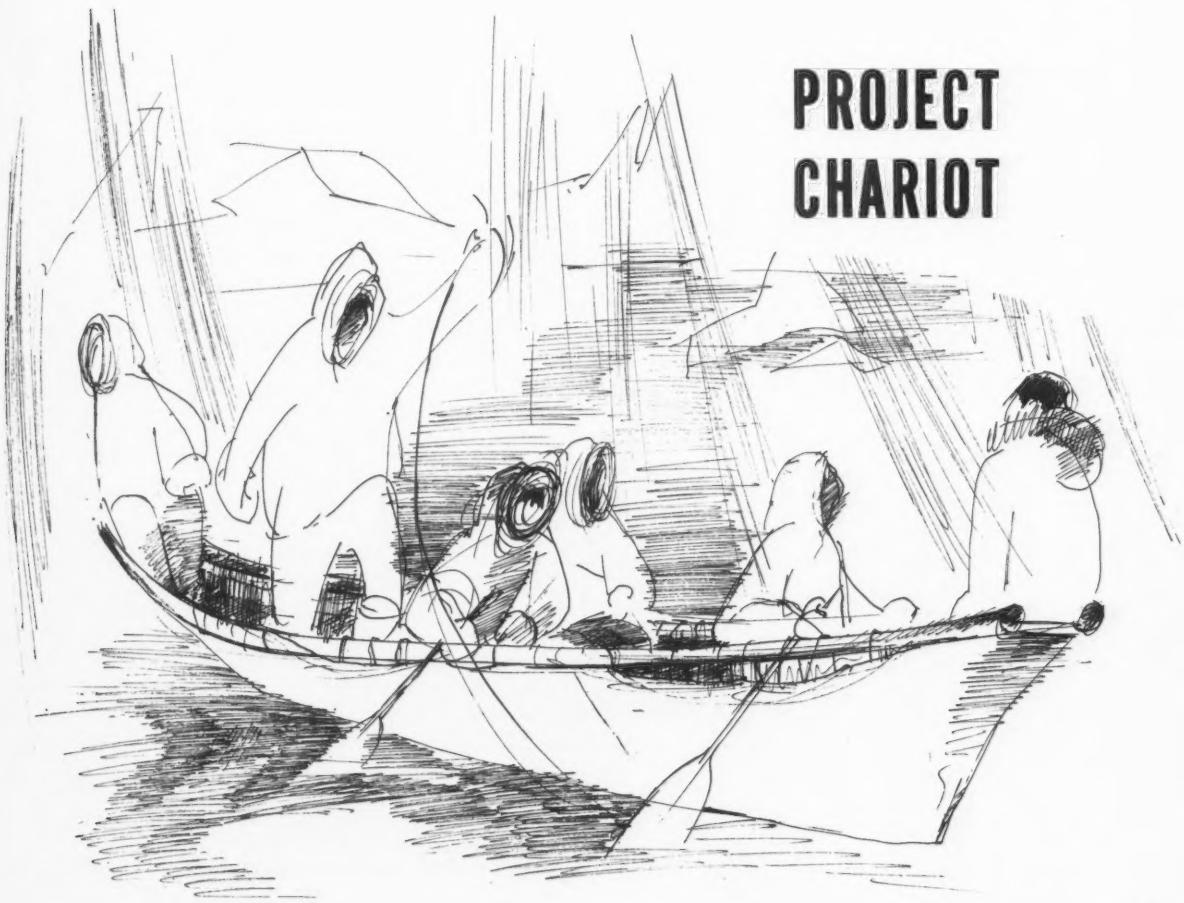
June 1961

NUCLEAR INFORMATION

Vol. III, Nos. 4–7



PROJECT CHARIOT

A complete report on the probable gains and risks of the AEC's Plowshare project in Alaska.

NUCLEAR INFORMATION

About This Issue

This issue of *Nuclear Information* is entirely concerned with Project Chariot, an AEC proposal to set off nuclear explosions above the Arctic Circle in Alaska. The purpose of this project is to find out if such explosions can be safely used to make big excavations – for harbors, canals, etc.

Project Chariot is the first proposed peaceful use of nuclear explosions that has inherent fallout dangers to people, animals, and plants.

This project also for the first time offers the public an opportunity to decide *in advance* whether or not the probable gains are worth the probable risks. This is the choice that has to be made about every nuclear project.

To make this choice, the basic facts must be known. The Committee for Nuclear Information is therefore pleased to present this report about Project Chariot as its contribution to the available knowledge.

In the preparation of the bulletin, we have consulted many persons outside CNI who have first hand acquaintance with the various aspects of Project Chariot. We are grateful to the following who have contributed to this issue:

Don Charles Foote, Program Leader for Human Geographical Studies in Point Hope, Point Lay and Noatak, Alaska, U. S. Atomic Energy Commission
John S. Kelly, Chief, Peaceful Nuclear Explosives Branch, U. S. Atomic Energy Commission
William O. Pruitt, Jr., Ph.D., Senior Scientist, Terrestrial Mammals Investigation, Project Chariot, U. S. Atomic Energy Commission; Associate Professor of Mammology, University of Alaska
Leslie A. Viereck, Ph.D., Assistant Professor of Botany, University of Alaska

We also wish to thank Berit Arnestad Foote, William D. Berry and Katherine Hohenemser for the drawings used.

---

* We are grateful to the Alaska Conservation Society for permission to use this material from their March 1961 *Bulletin*.

TABLE OF CONTENTS

Vol. III June, 1961 Nos. 4,5,6,7

The Known and the Unknown – the Nature of Nuclear Decision . . 1

The Purpose of Project Chariot *by John S. Kelly* 1

Excerpts from Statement of Gerald W. Johnson 2

Predictions of Fallout from Project Chariot
by Michael W. Friedlander 5

Biological Risks from Project Chariot
by Barry Commoner 9

Cape Thompson

The Place* 13

The People *by Don Charles Foote** 13

The Animals *by William O. Pruitt, Jr.* 15

The Marine Animals, Birds and Fish* 18

The Plants *by Leslie A. Viereck** 19

NUCLEAR INFORMATION is published nine times a year by the Greater St. Louis Citizens' Committee for Nuclear Information, 6504 Delmar Blvd., St. Louis 30, Missouri.

Issue Editor: Eric Reiss, M.D.

Associate Editor: Phyllis McPheeters

Scientific Advisory Board: Howard Blossom, H.T. Blumenthal, M.D., Ph.D., Barry Commoner, Ph.D., John M. Fowler, Ph.D., I.H. Herskowitz, Ph.D. Christoph Hohenemser, K.G. Lark, Ph.D., Norman Melechen, Ph.D., T.A. Pond, Ph.D., Eric Reiss, M.D., J.B. Reynolds, Ph.D., Wm. W. Sleator, Jr., Ph.D.

Subscription rates:
Individual: $2 per year
Organization (6 copies each issue): $5 per year

Note: The June *Nuclear Information* represents four issues combined.
Copyright 1961, Greater St. Louis Citizens' Committee for Nuclear Information.

PROJECT CHARIOT

The Known And The Unknown –

The Nature of Nuclear Decision

PROJECT CHARIOT is a symbol of the power – and the difficulties – of the nuclear age. The project is a part of the Plowshare Program for the development of peaceful uses of nuclear explosions. It calls for a nuclear explosion at Cape Thompson at a point on the northwest shore of Alaska. The explosion is designed to dig a hole about 1500 feet in diameter and a channel 2000 feet long to connect the hole to the sea. The job will require the explosion of 5 atomic bombs, one of 200,000 ton (TNT equivalent) size, and four of 20,000 tons each. (The Hiroshima bomb was 20,000 tons.)

Project Chariot demonstrates the enormous power of the nuclear age; in the instant of the blast, over 20 million cubic yards of dirt will be moved, a task which would otherwise take many months of labor by many men. But Chariot also demonstrates the inevitable risks that accompany nuclear power, for the explosions will produce radioactive debris which, if inadequately disposed of, may cause some harm to some people.

The Central Problem of Nuclear Age

Project Chariot poses the central problem of the nuclear age: how can we balance the value of a nuclear operation against the risk of possible harm, and thus decide whether the project is worth doing. The decision to set off the Chariot explosions has not yet been made, but plans are well under way. Before the order to explode the bombs is given, the Atomic Energy Commission, and the President of the United States will need to judge the probable value of the project against the risk of harm. The same judgment will have to be made by many others: Alaska state officials, the people of that state, and, in particular, the people who live in the immediate vicinity of Cape Thompson – the Eskimos of the villages of Point Hope and Kivalina. While the decision to set off the blast belongs, by law, to the AEC and to the President, the residents of Alaska, and indeed all citizens, need to make their own judgment, and so form the climate of assent – or disagreement – in which every agency of government must work.

In this issue of *Nuclear Information,* CNI hopes to present to those who must make this decision, a survey of the essential facts. To summarize the value of Project Chariot, we have asked Mr. John S. Kelly, Chief, Peaceful Nuclear Explosives Branch, AEC, to describe the useful results which they hope to obtain from the project. His statement will be found in the opposite column. Excerpts from a report by Dr. Gerald W. Johnson, director of the Plowshare project on the possible usefulness of nuclear excavations generally, will be found on page 2. The remainder of the issue is concerned with the facts needed to estimate the risks attached to the project.

The disparity in the space devoted to the expected gains and risks of Chariot is a lesson in itself. The estimation of the value of the project is a matter of engineering; it concerns the movement of earth by the force of explosives; the relative cost and efficiency of different earth-moving techniques, and the economic importance of large earth-moving projects in the future. While technical in content, this problem deals with only a few aspects of nature, principally mechanics and geology.

The Purpose of Project Chariot

by John S. Kelly, Chief, Peaceful Nuclear Explosives Branch, U.S. Atomic Energy Commission

THERE is a great potential for a number of peaceful applications of nuclear explosives. One of the more promising of these applications is excavation. All available data indicate that large scale nuclear excavation can be much less costly and time consuming than conventional excavation. Thus, nuclear excavation can make possible many projects which are neither feasible nor economically justifiable with conventional methods. However, as a first step toward such projects additional data are required on the phenomena associated with crater-producing nuclear detonations. The phenomena on which more data are needed include but are not necessarily limited to:

1. The entrapment and distribution of radioactive debris.
2. The precise relations between yield, depth of burst and crater characteristics.
3. The effects of simultaneous detonation of a row of charges.
4. The effect of nuclear excavation on the biota (i.e., living things).

Project Chariot is an excavation experiment which has been designed so that it will, if conducted, provide these and other data. Although the Commission has authorized these investigations it has not approved the nuclear detonations and would not give such approval without assurance that the experiment can be conducted without jeopardy to the local inhabitants or to the plants and animals from which they derive their living.

PROJECT CHARIOT

The Known And The Unknown –

The Nature of Nuclear Decision

PROJECT CHARIOT is a symbol of the power – and the difficulties – of the nuclear age. The project is a part of the Plowshare Program for the development of peaceful uses of nuclear explosions. It calls for a nuclear explosion at Cape Thompson at a point on the northwest shore of Alaska. The explosion is designed to dig a hole about 1500 feet in diameter and a channel 2000 feet long to connect the hole to the sea. The job will require the explosion of 5 atomic bombs, one of 200,000 ton (TNT equivalent) size, and four of 20,000 tons each. (The Hiroshima bomb was 20,000 tons.)

Project Chariot demonstrates the enormous power of the nuclear age; in the instant of the blast, over 20 million cubic yards of dirt will be moved, a task which would otherwise take many months of labor by many men. But Chariot also demonstrates the inevitable risks that accompany nuclear power, for the explosions will produce radioactive debris which, if inadequately disposed of, may cause some harm to some people.

The Central Problem of Nuclear Age

Project Chariot poses the central problem of the nuclear age: how can we balance the value of a nuclear operation against the risk of possible harm, and thus decide whether the project is worth doing. The decision to set off the Chariot explosions has not yet been made, but plans are well under way. Before the order to explode the bombs is given, the Atomic Energy Commission, and the President of the United States will need to judge the probable value of the project against the risk of harm. The same judgment will have to be made by many others: Alaska state officials, the people of that state, and, in particular, the people who live in the immediate vicinity of Cape Thompson – the Eskimos of the villages of Point Hope and Kivalina. While the decision to set off the blast belongs, by law, to the AEC and to the President, the residents of Alaska, and indeed all citizens, need to make their own judgment, and so form the climate of assent – or disagreement – in which every agency of government must work.

In this issue of *Nuclear Information,* CNI hopes to present to those who must make this decision, a survey of the essential facts. To summarize the value of Project Chariot, we have asked Mr. John S. Kelly, Chief, Peaceful Nuclear Explosives Branch, AEC, to describe the useful results which they hope to obtain from the project. His statement will be found in the opposite column. Excerpts from a report by Dr. Gerald W. Johnson, director of the Plowshare project on the possible usefulness of nuclear excavations generally, will be found on page 2. The remainder of the issue is concerned with the facts needed to estimate the risks attached to the project.

The disparity in the space devoted to the expected gains and risks of Chariot is a lesson in itself. The estimation of the value of the project is a matter of engineering; it concerns the movement of earth by the force of explosives; the relative cost and efficiency of different earth-moving techniques, and the economic importance of large earth-moving projects in the future. While technical in content, this problem deals with only a few aspects of nature, principally mechanics and geology.

The Purpose of Project Chariot

by John S. Kelly, Chief, Peaceful Nuclear Explosives Branch, U.S. Atomic Energy Commission

THERE is a great potential for a number of peaceful applications of nuclear explosives. One of the more promising of these applications is excavation. All available data indicate that large scale nuclear excavation can be much less costly and time consuming than conventional excavation. Thus, nuclear excavation can make possible many projects which are neither feasible nor economically justifiable with conventional methods. However, as a first step toward such projects additional data are required on the phenomena associated with crater-producing nuclear detonations. The phenomena on which more data are needed include but are not necessarily limited to:

1. The entrapment and distribution of radioactive debris.
2. The precise relations between yield, depth of burst and crater characteristics.
3. The effects of simultaneous detonation of a row of charges.
4. The effect of nuclear excavation on the biota (i.e., living things).

Project Chariot is an excavation experiment which has been designed so that it will, if conducted, provide these and other data. Although the Commission has authorized these investigations it has not approved the nuclear detonations and would not give such approval without assurance that the experiment can be conducted without jeopardy to the local inhabitants or to the plants and animals from which they derive their living.

Evaluating Risk a Complex Problem

But now consider what is involved in an estimate of the possible harm that may result from the project's radioactive debris. For this purpose we must know where the fallout goes, how it enters plant life and spreads through the complex food web that ties plant, animal and man together. We need to know the food habits of the nearby residents which are in turn related to their history and their outlook on life. To evaluate the risk of Chariot, we shall need to consider matters in the fields of meteorology, radiation chemistry, oceanography, plant ecology and physiology, animal ecology and nutrition, human nutrition and sociology.

The complexity of this problem has been recognized by the AEC, for the Commission has asked a number of specialists in these fields to study the area of the proposed blast, and to provide the basic data required to evaluate the possible harm to man and animal. CNI is fortunate that three of these scientists have agreed to summarize their findings in this issue of *Nuclear Information.* Their articles (see pages 13 through 20) deal with the plant and animal life of the Cape Thompson region and the way in which the Eskimo residents depend on them. Finally, on the basis of this background material, and the available physical facts regarding nuclear debris and fallout, CNI scientists have made estimates of how much radioactive fallout might be released by the proposed blast, and what possible harm might result from this fallout (see pages 5 and 9).

Cape Thompson – A Distant View

The problem is a complicated one. Physical and biological factors are so tightly interwoven as to hide – from the distant viewer – seemingly small facts which, on closer examination, turn out to be decisive and far-reaching in their effects. Viewed from a distance, the Cape Thompson region might at first glance appear to be ideally suited for a nuclear blast. The site is at Ogotoruk Creek, a small stream which empties into the Chukchi Sea at a point about 100 miles north of the Arctic Circle. The nearest people are at the villages of Point Hope, 35 miles north, and Kivalina, about 40 miles south. Total population of both villages is about 700. The coast is ice-bound for ten months of the year. No one lives inland from the coast; there are no harbors, no commercial fishing and no industry, save Eskimo handcraft and big game (polar bear and grizzly) hunting; there are no roads – communication is by airplane in summer and dogsled in winter.

Closer View Gives Different Picture

But a closer view of the life of the region, which is described in Mr. Foote's article (page 13), gives us a different picture. Although no one lives along the coast between Point Hope and Kivalina, Foote, who has spent many months in the region, records an extensive pattern of travel up and down the coast and inland for many miles (see maps page 14). This travel is essential to the Eskimos' livelihood. As he points out, the great part of their food and clothing comes from the land. Food is so scarce in northwest Alaska that vast unpopulated areas are required to support the life of even two small villages. Unlike a resident farmer who could, if he had to, survive off the products of a few acres of land, an Eskimo must scour miles of countryside to find and gather his food: fish, ducks and sea mammals in the autumn, and polar bear and land animals in the winter. Caribou, the most important food-animal, is hunted in all seasons. Thus, land which is empty of people for most of the year is essential for the survival of the residents of a few coastal villages.

Dependence of Eskimo on Biological Environment

The closer view of Cape Thompson shows that the Eskimo's life is closely enmeshed in a complex chain of relations with animals and plants. Over thousands of years he has discovered that to survive in this bleak land, man must find his precise niche in the intricate pattern of plant and animal life. With great ingenuity, the Eskimo has learned to track the caribou, to catch the bearded seal on the ice, and spear the whale in offshore waters. Nearly every land and water animal is used for food or clothing. Walrus tusk is useful construction material and is made into jewelry. Even the tusks of

---

Possible Uses of Nuclear Explosions for Excavations

Excerpts from statement of Dr. Gerald W. Johnson, director of Plowshare Program, Lawrence Radiation Laboratory, University of California, before Hearings on Frontiers in Atomic Energy Research, Joint Congressional Committee on Atomic Energy, March 22-25, 1960.

"Of all the applications that have so far been considered, the one we are most certain of accomplishing with very large economic gains is in earth moving. Some areas in which the excavating potentialities can be exploited are the construction of harbors, canals and other waterways, the removal of overburden in some special situations to permit open-pit mining of ore, the construction of reservoirs for water supply or flood control, and the damming of rivers or streams to provide for water storage, which would also provide recreational lakes. The economic advantages seem clear . . .

"Specific excavation projects that have been or are under study which could be initiated on completion of the experimental program outlined are as follows:

1. A small harbor near Katalla on the Coast of the Gulf of Alaska to permit exploitation of possible coal and oil reserves. This harbor would be similar in size to the Chariot harbor experiment.
2. Other harbors have been suggested along the West Coast of South America, but specific studies have not been made.
3. A paper study has been made of the feasibility of constructing a sea level canal across the American Isthmus.
4. Although it has not been evaluated in detail, there are undoubtedly sites where small harbors could be developed to permit access of small boats to important recreational islands.
5. An analysis has been made of the landslide created by the earthquake near Yellowstone Park last year which dammed the Madison River to produce a lake. It has been estimated that a 100 kt explosion placed at scaled depths similar to the 100 ton explosion in Nevada would produce the same amount of earth movement. The total cost to accomplish this program would be less than $5,000,000. The results from the projected 5 kt Russian explosions would be helpful here.

"This list of possibilities is by no means complete, but it is illustrative of the kinds of undertakings that would be possible in a few years."

fossil mammoths are put to use. From his survey of the economy of the village of Point Hope, Foote concludes that it "depends on the local biological environment for 80% of its food, 30% of its clothing but 80% of its transportation means." (See "The People," p. 13, ref. #4.)

All this indicates that the Eskimo in northwest Alaska is an inextricable part of the web of plant and animal life. Anything that influences almost any segment of the region's biology will have an immediate effect on the Eskimo. He cannot turn to alternative foods from elsewhere because his cash income is insufficient. This means that in evaluating the effect of Project Chariot on the Eskimo, we must determine how it will affect almost every part of the region's animal and plant life.

The "Food Web" Studied

This task has been undertaken by the biologists who have been studying the problem for the AEC. Their articles summarize much of what they have learned. On page 15 is illustrated the food web that the Alaska scientists have established for the area. It shows the net of food relationships upon which man in Alaska depends. The caribou is especially important in the Eskimo livelihood, and in considering how fallout from the Chariot blast will affect these Alaskans, we need to pay particular attention to this animal.

Again the Chariot project reveals its hidden difficulties. As a source of meat, the caribou presents problems quite unfamiliar to those of us who use domestic animals. The caribou is wild, and ranges in great herds throughout the uninhabited regions of Alaska. Its food habits are not under human control. Unlike cattle, sheep and other familiar grass-grazing animals, caribou eat a very unusual plant, lichen.

Lichens Especially Susceptible to Fallout

Here the Chariot problem takes another unexpected turn. Lichens are remarkable plants: they are a mutually supporting team of two different plants – a fungus and an alga. Unlike ordinary plants, lichens have no real roots; they absorb their mineral nutrition from dust in the air. They are therefore uniquely susceptible to fallout. For this reason, as reported on page 10, lichens contain much more strontium 90 from atomic-test fallout than do ordinary plants of the same area. Hence, the caribou which favors lichens as a food, also tends to absorb a rather high level of Sr90 – which is evident from the extraordinary radioactivity of caribou meat, antlers and stomach contents.

Taking possible fallout problems into account, it has been suggested that the Chariot blast might be set off in the spring so that the snow cover would prevent the fallout from coming down on the plants; then in the spring thaw, the snow would melt and flush the fallout away from the plants on land. But as indicated by the Eskimo name for a point near the Chariot site – Ahneeyouyaktuvik ("the place where the wind has hardened the snow so that a snow house can be built") – the characteristically strong winds of the Ogotoruk Creek valley may blow away a good part of the winter snow cover, and leave the lichens more exposed to fallout than might be supposed (see page 13).

Existing Radioactivity in the Region

Another problem that affects any attempt to evaluate the possible effects of Chariot's fallout, is the determination of how much radioactivity is already in the region because of world-wide radioactive fallout from the

Caribou

nuclear explosions set off between 1945 and 1958. Again the situation at Cape Thompson is a deceptive one. Because of the way in which world-wide fallout descends from the stratosphere to the earth, regions near the poles receive relatively little fallout. The fallout now on the ground at Point Barrow, Alaska, is well below that found elsewhere in the U. S. One might expect, therefore, that animals and humans in the arctic regions of Alaska (which include the Cape Thompson area) would now contain relatively little Sr90.

Sr90 Levels in Alaskans

But such is not the case. Evidence reported in the article on page 9, shows that Sr90 levels in Alaskans are generally higher than those found in inhabitants of temperate zones, and that the levels in Alaskan caribou are considerably higher than those in domestic animals elsewhere in the U. S.

The reason for this is suggested by the unusual biology of the Cape Thompson region: the importance of caribou as human food; the fondness of caribou for lichens; and the special avidity for Sr90 which results from the lichens' unique biological properties. The difference in the biological fate of Sr90 in arctic and temperate regions is striking: Steer raised in the Nevada atomic test zone, which has a ground Sr90 level of 100-140 mc/mi^2 (millicuries per square mile), have about 25 strontium units (micromicrocuries of Sr90 per gram of calcium) in their bones. According to this ratio of ground Sr90: bone Sr90 (125/25), we would expect caribou in northern Alaska where the ground Sr90 is no more than 25 mc/mi^2, to have about 5 strontium units in their bones. Actually caribou now have in their bones, 100-150 strontium units, or about 20-30 times more than would be expected if they behaved like steer in temperate U. S. The Sr90 content of caribou (and reindeer) meat is probably considerably higher than that

of any other animal used for food anywhere in the world.

And so, by a peculiar, and probably unpredictable, chain of circumstances, what appears from afar to be a place well-suited for a nuclear experiment, turns out on closer examination to be peculiarly liable to any risk of biological damage that might result from the radioactive fallout produced by the test.

How Much Fallout From Chariot?

But there remains the final question of determining how much radiation from the Chariot blast might reach humans and the animals important to them, and what the possible harm might be. Here, we again face a characteristic difficulty of the nuclear age – the uncertainty that arises when we try to predict, from our experience with small conventional explosions, the results of big nuclear ones. If the Chariot explosion is carried out, it will be only the fifth crater-producing underground nuclear explosion in history. With a total experience based on only four blasts, it is rather difficult to predict exactly how much of Chariot's radioactivity will be ejected into the air and spread in the form of fallout. Yet it is precisely this figure which is required if we are to make any estimate of the radioactive danger that might result from the explosion. Any uncertainty in the predicted value of the released radioactivity leads to that much uncertainty in any estimates of the possible danger.

The problem of making this prediction is analysed in detail on page 5. This analysis shows that the available information about underground nuclear explosions is far too slight to permit any but the most approximate estimates of the expected fallout. Reports from the Livermore Laboratory conclude that the fallout released by the explosion will probably represent about 5% of the total radioactivity, and certainly no more than 15%. But Dr. Friedlander's analysis of the problem shows that there is no good basis for even so imprecise an estimate – and that the probability of obtaining a 25% fallout yield is as high as the probability of a 5% yield. For these reasons, and because of uncertainties regarding the unusual wind conditions in the Ogotoruk Creek valley, Dr. Friedlander concludes that the fallout from the Chariot explosions might readily be ten times higher than that predicted in current AEC reports.

If we are this much uncertain about the amount of fallout that the Chariot explosion might produce, we are even more uncertain about its possible biological effects. As indicated on page 12, a number of questions need to be answered before any reasonably accurate prediction about these effects can be made. What explains the unusual Sr90 metabolism of lichens? How much of the lichen contaminated by fallout from the Chariot blast would be eaten by caribou? Would it be practical to fence off the most radioactive areas and exclude caribou from them? How does the Eskimo's unusual diet affect his mineral metabolism and Sr90 absorption?

Tigara, Alaska. B. Arnold

Some General Conclusions

In view of these and other gaps in the knowledge about the fallout problem, any prediction regarding the biological effects of the proposed Chariot explosion must be regarded as very inexact. Nevertheless, from what is already known about the unusual biological situation in Alaska, certain general conclusions (summarized on page 12) are possible:

- "Because of the unique mineral nutrition of the lichens, which avidly absorb fallout, the caribou – which feed on lichens – and the humans who eat the caribou, appear to be higher in Sr90 content than any other group in the world.
- The fallout from the proposed Chariot explosion will add to the present Sr90 levels by an amount that cannot now be estimated with any degree of precision.
- In the present state of knowledge about the effects of radiation, no firm prediction can be made regarding the ultimate harm that may result from either the present Sr90 levels, or from any increase that may be brought about by Chariot fallout. However, according to the current philosophy of radiation protection, it is assumed that every increase in radiation exposure carries with it in an increased risk of disease."

The Chariot test, if carried out, would be one of the first projects for the peaceful application of nuclear explosions. Risks and uncertainties are to be expected with such a new venture. But the special biological situation at the proposed site of the explosion, Cape Thompson, leaves little margin for error.

These are the risks – known and unknown – that must be weighed in deciding whether the experimental explosion at Cape Thompson should be set off.

B.C., M.F., C.H., E.F

PREDICTIONS OF FALLOUT FROM PROJECT CHARIOT

by Michael W. Friedlander

THE MAIN problem that needs to be solved in evaluating the possible risk from Project Chariot is the determination of the amount of radioactivity which will be produced by the proposed underground nuclear explosion, and the fraction of this which will reach places in the food chain where its effects might be detrimental to animals and people.

Four Aspects

For this calculation, four aspects can be separated: a) the size of the explosion, which will determine the total amount of strontium 90 and other radioactive elements produced; b) the fraction of this radioactivity which escapes into the air (termed the "vented yield"); c) the expected distribution of this vented radioactivity, as fallout, in the region around the explosion; and d) how much of this fallout will end up in plants, animals and man, and what possible harmful effects it may have on these living things. This article deals with the physical parts of the above problems, upon which depend all estimates of possible biological harm.

The physical events which occur when nuclear explosions are set off at the ground surface, or below it, have been the subject of much study by AEC laboratories, in particular, the Livermore Laboratory of the University of California. This work has been described in a number of available reports, and these UCRL reports, and others published by the AEC, provide most of the information used in this article. In addition CNI is indebted to Mr. John S. Kelly, Chief of the AEC Peaceful Nuclear Explosives Branch, who met with the CNI Technical Division on April 19, and discussed the program in detail.

Original plans for Project Chariot called for nuclear explosions totaling 4.5 megatons (equivalent to 4.5 million tons of TNT). However, the program has twice been reduced in size and present plans call for one 200,000 ton explosion buried at a depth of about 800 feet and four 20,000 ton explosions, each at a depth of 400 feet.

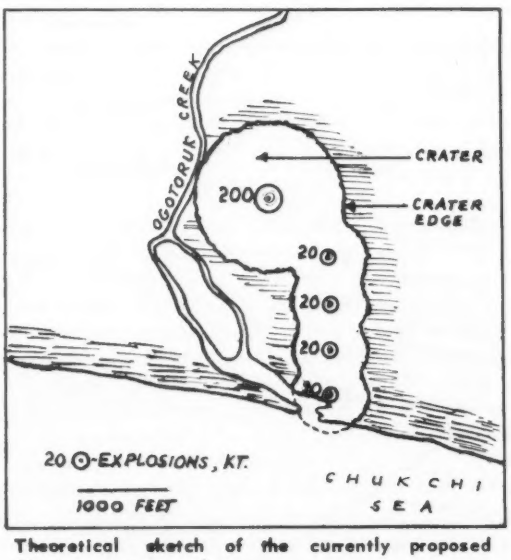
It is predicted that 5% of the total radioactive yield produced will emerge as fallout. This is given as the most probable value; the actual value is not expected to be lower than about 1% nor higher than about 15%. Based upon the 5% value and an assumed wind pattern, the distribution of the local fallout is also predicted; the figures are (for Sr90): 370 mc/mi^2 (millicuries per square mile) at about 28 miles downwind from the explosion site, and 37 mc/mi^2 at 55 miles. The overall shape of the fallout zone is expected to be elongated and about four or five times longer (in the downwind direction) than it is wide. The predicted levels of fallout have been published in the form of contour lines which correspond to 5R and 0.5R lifetime gamma-ray doses. (R = roentgen, a measure of radiation. A lifetime dose is that which a person would receive if he were to stay at that place continuously until the end of his life.) The contours of radioactivity do not include beta-activity such as Sr90.

These predictions are from a UCRL report[10] on the expected fallout from the Chariot project. Since they provide the ultimate basis for estimating the possible risk to animals and man from the proposed explosion, it would appear to be useful to determine how they are made, so that some estimate can be given of their accuracy and reliability.

Underground Tests in Nevada

The factual basis of these predictions rests on the results obtained from a number of underground explosions in Nevada. Most of the tests have been made with ordinary chemical explosives, but some underground tests were made with nuclear explosives. In these tests it was possible to measure the total explosive yield, the sizes of the craters produced, and, for the nuclear explosions, the fraction of the total radioactive yield which escaped into the air as fallout. In each case, the actual depth at which the explosive was buried was, of course, also known (but with some uncertainty).

However, none of the past shots occurred under the precise conditions which will be used in the Chariot project. The largest Nevada underground nuclear explosion was the 19,000 ton Blanca shot, but the Chariot



Theoretical sketch of the currently proposed Chariot crater-complex.

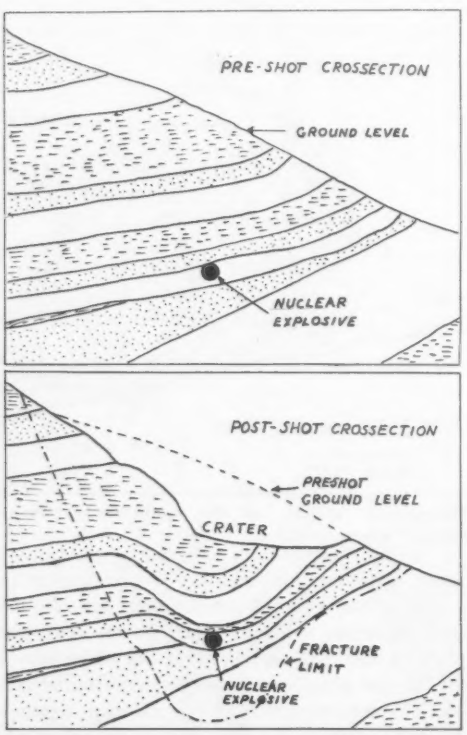
experiment will include a 200,000 ton explosion. Although the other Chariot explosions are 20,000 tons each, and therefore resemble the Blanca test, they are planned for a 400-foot depth, while the older test was at 835 feet. In the absence of actual experience under the exact conditions expected in the Chariot explosion, it becomes necessary to develop some *general* rule, based on the past tests, from which one can predict the outcome of the new proposed test.

To develop such a general rule for underground explosions, we must consider how the percent of radioactivity, which escapes to the air ("vented yield"), and the size of the crater, vary with the size of the explosion, and the depth at which it occurs.

The Vertical Ejection Effect

The main physical effect of interest is how much of the explosive force is exerted to eject debris vertically into the air, for this factor will determine both the size of the crater and the amount of vented radioactivity. The vertical ejection will, of course, depend on the depth of the explosion. Near the surface almost all of the explosive force will go upward, but if the explosion is deep, the pressure of overlying material will tend to suppress the vertical effect. The vertical ejection effect will also increase with the total force or size of the explosion; but from geometrical considerations, the effect is expected to depend on the cube root of the total explosive force (W) (or W raised to the power 1/3, which is written as $W^{1/3}$). As a result, from theoretical considerations we can expect the vertical ejection resulting from an explosion to be related to the depth of the explosion (D) divided by the 1/3 power of its total force, or yield (W). This expression which can be written as $D/W^{1/3}$ is called the "scaled depth."

How well these theoretical relationships work out in actual practice can be determined by experiments. Ordinary explosives of various sizes are set off at different depths, and the vertical effect is estimated from the size of the resulting crater. From such experiments it is found that the scaled depth is a better measure of the results of many explosions when the power factor is 1/3.4 or 1/3.5 rather than 1/3.0. However, for very large explosions, or very deep ones, there are some indications that a factor of 1/4.0 gives better predictions. In general, the experiments with ordinary explosives show that some idea of the expected vertical effect of an explosion can be gained from the scaled depth calculated from the values of D and W, but that there is some uncertainty regarding the power to which W should be raised in the equation. Thus, although the scaled depth seems the best way to predict the vertical effect of an explosion (i.e., the size of the crater and, in the case of nuclear explosions, the vented radioactivity), there is some uncertainty as to how it should be calculated, especially for big nuclear explosions.



Actual scale-drawn cross-section for the Neptune test, one of the four underground shots relevant to predicting the fallout from Chariot. Neptune resembles Chariot most closely of the four. As can be seen, the shot was performed on a 30° slope (on a mesa edge), it formed a shallow crater from which 1-2% of the total fission yield was vented. The fracture limit indicates the extent of crushed rock.

TABLE I

Event	Total yield W (tons)	Actual depth, D (feet)	Scaled depth given in UCRL 5917	Corrected scaled depth ($D/W^{1/3.4}$)	Percentage vented yield
Jangle-U	1,200	17	16	16	> 80
Teapot-S	1,200	67	63	63	90
Neptune	115	99	220*	187	1 - 2
Blanca	19,000	835	310**	350	< 0.5
Logan	5,000	830	485**	518	0
Chariot	200,000	800	160	168	?
	4x20,000	400	160	166	?

*Incorrect; based on old value of total yield.
**Incorrect; based on $W^{1/3}$ instead of $W^{1/3.4}$.

Regardless of how the scaled depth is calculated, its reliability for the prediction of the effect of an explosion will depend on how precisely one knows the value of W, the total explosive force, and D, the depth of the explosion. Therefore, if we wish to use the results of the past underground explosions to predict the results of the Chariot blast, we must determine how reliably we know their values of D and W.

Force and Depth of Burial of Past Test Explosions

There is some uncertainty regarding the total explosive force of the past underground explosions. The Neptune shot was quoted for quite some time as being 90 tons.[1,2,3,5,6,8] Further measurements at the site led to a revised figure of 115 tons.[7,9,10] Similarly, the Blanca event was first quoted as 23,000 tons, and now as 19,000 tons.[1,2,3,4,8,9,10] Two of the earlier explosions, Jangle-U and Teapot-S have both been consistently quoted at 1,200 tons, but it is not clear that there has been any check on these as in the case of Neptune and Blanca. In any event, the sizes of Neptune and Blanca were not predicted accurately in advance, and measurements made *after* they took place have resulted in values differing by 25%.

There is also some uncertainty about the depth of burial of the Neptune, Blanca and Logan tests explosions, which were exploded in galleries driven into the side of a mesa in Nevada. For instance, Neptune was exploded 99 feet from the nearest surface but 110 feet vertically below the surface. The scaled depth (using $W^{1/3.4}$) is thus 187 feet, or 208 feet, or somewhere in between.

The actual vented yields of radioactivity have been measured in past underground explosions, and this and other relevant information is contained in Table I.

The data in Table I are taken from the most recent AEC report (UCRL 5917), devoted explicitly to the calculations of the vented yield for project Chariot. In this report the total yield of the Neptune explosion is given as 115 tons, and the scaled depth calculated from it, is listed as 220. But we have been informed by Mr. Kelly of the AEC that these figures are incorrect. A scaled depth of 220 results from the earlier estimate of the Neptune total yield (90 tons); the correct scaled depth calculated from the latest total value is 187. This report also gives a scaled depth for the Blanca shot of 310, but this is also incorrect. This value results from dividing the depth of the Blanca shot which is 835 feet [1,2,3,4,8,9] by $W^{1/3}$. As already indicated, the proper factor is $W^{1/3.4}$ which gives a scaled depth of 350. Similarly, the scaled depth of 485 given for the Logan shot in this report is calculated from $W^{1/3}$ rather than $W^{1/3.4}$. However the remaining calculations of scaled depths in UCRL 5917 do use the now accepted factor of $W^{1/3.4}$. The necessary corrections have been noted in Table I.

There are in all, four points from which predictions regarding Chariot must be made: Jangle-U, Teapot-S, Neptune and Blanca. (Other tests were buried deeper or were so much smaller that no venting was observed, and so these supply no pertinent information.) Of the four points, Jangle and Teapot were tests conducted before the Plowshare project was initiated, and there is some question about the reliability of the vented yield figures. Neptune and Blanca have both been subject to remeasurement and change of quoted data, and for both, the effective depth of burial is probably rather larger than that quoted, since both were exploded below a sloping surface. This means that their observed vented yields could correspond to greater scaled depths, and that at their quoted scaled depths one might very well get a greater vented yield.

Prediction of Vented Radioactivity

Our problem is now more clearly defined: Given the facts of Table I, which summarizes for the four relevant underground nuclear explosions the relationship between the vented yield of radioactivity and the best available measure of the vertical effect of an underground explosion (the scaled depth), what is the predicted vented radioactivity for the proposed Chariot explosion? Table I shows that the scaled depths expected for the two types of Chariot explosions are 166 and 168 feet. Unfortunately, none of the four earlier tests were carried out at this scaled depth. The closest past test is Neptune at a scaled depth now calculated as 187 feet, but in earlier calculations this was given as 220 feet. Further, there is a large difference in the total sizes of the Neptune shot (115 tons) and the Chariot shots (20,000 and 200,000 tons) so that uncertainty in the scaling factor (i.e., 1/3.4) applied to the value of W, could lead to a considerable uncertainty in the predicted effect of the explosion.

In this circumstance all that can be done to facilitate a prediction is to attempt to develop some general mathematical relationship that ties together the results of all four previous underground explosions. The Livermore investigators have produced such a mathematical relationship, which is shown as the main curve in Fig. 1. Although the curve has been published,[5,6] no report is

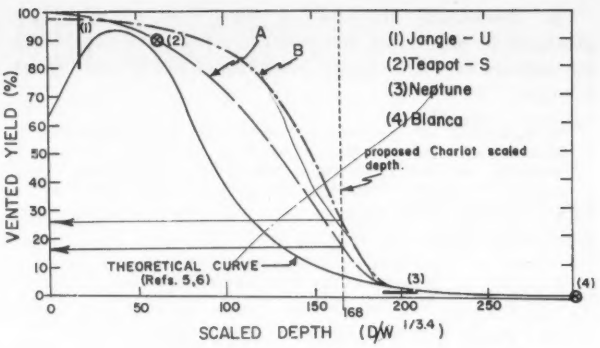


Fig. 1

available as to the mathematical theory used to construct it, and the assumptions basic to the calculations. The chief purpose of the curve is to permit one to decide, from the expected scaled depth of the Chariot explosions (166 – 168 feet), what part of the explosions' radioactivity will be vented into the air. It will be seen from Fig 1, that at this scaled depth, the theoretical curve predicts a vented yield of 5%; this relationship is the source of the 5% figure which the AEC proposes to use in estimating the possible biological effects of fallout from the Chariot explosions.

A Final Question

We can now reduce our problem to a final question: How certain can we be that the curve relating the points based on four previous nuclear explosions crosses the 166 – 168 foot scaled depth mark at a vented yield of 5%? Might the curve have some slightly different shape, which would give rise to a different expected vented yield?

The reliability of the theoretical curve cannot be very great. Of the four points, two are at very large vented yields, while the other two are nearly at zero. In other words, all that the past data tell us is that in some way, the curve must fall from a vented yield of 90% for Teapot-S (at scaled depth of 63 feet) to a vented yield of 1-2% for Neptune (at scaled depth of 187 - 208 feet). There is no reliable way of knowing the steepness with which the curve descends from Teapot-S to Neptune – and this is the crux of the matter.

In discussing this, Mr. Kelly stated that different groups, working with different assumptions, had produced calculated curves but that none of the calculations had produced an estimate of more than 15% vented yield. It seems to us that on the basis of only four points, a *variety* of equally plausible curves could be drawn to pass through these points or their regions of uncertainty. As examples, we have drawn curves A and B in the figure which would predict 16% and 26% as vented yields – considerably more than the current Livermore prediction. In all, it seems not at all unreasonable that the yield could be five times the predicted 5%.

Uncertainty of Predictions

This considerable uncertainty about the way in which vented yield is related to scaled depth is reflected in the discussions of the relevant problems in several of the Livermore laboratory reports. Some examples follow.

In discussing the use of data from chemical explosions in predicting the results of nuclear explosions the authors of UCRL report 5766 (April 1960) state (page 12) that:

> "Comparison of the Neptune data and high explosive data in tuff indicates that small high explosive charges probably are not completely reliable for predicting the results of nuclear cratering explosions in some media."

UCRL report 5676 states (page 21) in connection with data derived from the Neptune test explosion:

> "However, since this event was on a hillside and placed in a relatively large room, the data may not be significant."

In considering the predictive value of the four underground shots, this same report states (page 21):

> "From these four events it is obviously a wide stretch of one's imagination to predict a great deal about the variation of crater width as a function of nuclear yield and depth of burial."

In effect, from the little that is now known about underground nuclear explosions, or about underground explosions of any kind, the predicted value of 5% for the vented radioactivity of the proposed Chariot explosions must be regarded as so uncertain as to suggest, with equal probability any value ranging from 1% to about 25%.

Wind Conditions a Factor

The final factor that must be considered in determining the amount of fallout that will descend on the region around the Chariot blast is local wind conditions at the time of the explosion. In the estimate of local fallout reported in the Livermore report the wind velocities used in the calculations were those measured at Kotzebue, 210 miles to the southeast of the proposed Chariot site.[10] Considering the known variability of the weather conditions along this coast and the unusually high winds characteristic of the Ogotoruk Creek valley, it appears highly questionable whether observations from any place but the Ogotoruk Creek could be used for predictions applicable to the Chariot explosions.

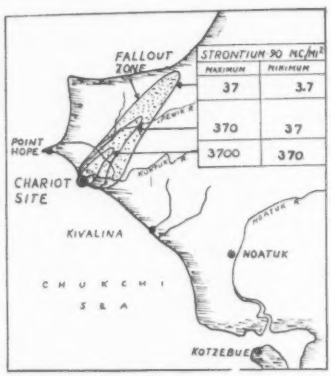
Further, the frozen material which comprises the bed of the creek might well shatter into particles of sizes quite different from those found in the Nevada tests, and the radioactivity might very well be distributed over a much greater area.

On any reasonable and cautious basis, it seems that a factor of 2 or more could well enter from the funnelling effects of the wind in the creek and from the different particle size.

These considerations show that the prediction made by the Livermore Laboratory that 5% of the radioactive yield of the Chariot explosion will be ejected in the form of fallout cannot be accepted as the only basis for estimating the possible harm from the explosion. The vented fallout may well be 5% or 25%; and the special wind effects in the Ogotoruk Creek valley may double the expected value of the fallout spread downwind from the blast. Thus, a conservative judgment of the fallout expected from Chariot would require that the AEC estimates be multiplied by 10.

It seems from the published data, that for each 28 miles downwind, one reaches a contour tenfold lower in activity. Putting in now our suggested factor of 10, we find:

(1) The 5R lifetime dose contour at 28 miles proposed on the basis of AEC calculations, now corresponds to 50R,
(2) the 0.5R contour now corresponds to 5R,
(3) a further 28 miles away we shall find the new 0.5R contour, i.e., on the northern coast, around Cape Beaufort, and
(4) the Sr90 levels will be 3700, 370 and 37 mc/mi^2 at these three contours, and a swathe of land, sealing off the Cape Hope peninsula, will have an ave-age Sr90 concentration of around 5300 mc/mi^2. Of course, the most intense of this will be near the bomb site, but the average level between 28 miles from the site and the coast will still be above 500 mc/mi^2.



Fallout contours, with CNI maximum and minimum estimates for strontium 90 values.

Thus, if the AEC estimates (based on a 5% vented yield) prove to be an accurate prediction of the fallout from the Chariot explosion, a zone of land from a point 28 miles downwind from the blast reaching to the coast north of Point Hope, will have an average Sr90 level of 50 mc/mi^2 deposited on it. From the foregoing consideration we see that the fallout in this zone might, however, turn out to be as high as 500 mc/mi^2. To judge the significance of these figures, it should be recalled that the fallout now on the ground in northern Alaska (from past nuclear tests) averages about 15 mc/mi^2. Thus, if the Chariot explosion is carried out, it may raise the Sr90 levels in the fallout zone to anywhere from about 3 to 30 times their present levels.

REFERENCES

1. UCRL 5458, February 5, 1959: "Mineral resource development by the use of nuclear explosives" by Gerald W. Johnson.
2. University of Missouri School of Mines, and Metallurgy Bulletin, Technical Series 97: "Phenomonolgy of contained nuclear explosions" by Gerald W. Johnson and Charles E. Violet.
3. UCRL 5626,: July 8, 1959: "Underground nuclear detonations" by G. W. Johnson, G. H. Higgins and C. E. Violet.
4. SCTM 78-59 (51) (Sandia Technical Memorandum): March 1959: "Earthmoving by nuclear explosives" by M. L. Merritt.
5. UCRL 5676, May 14, 1959: Plowshare Symposium.
6. "Plowshare Program" by Gerald W. Johnson, March 22, 1960.
7. UCRL 5766, April 19, 1960: "The Neptune Event" by A. V. Shelton, M. D. Nordyke and R. H. Goeckermann.
8. UCRL 5840, January 19, 1960: "Industrial and scientific applications of nuclear explosions" by G. W. Johnson.
9. UCRL 5917, November 1, 1960: "Excavation with nuclear explosives" by G. W. Johnson.
10. UCRL 6249-T: October 26, 1960: "Distribution of radioactivity from a nuclear excavation" by R. E. Batzel.
11. Alaska Conservation Society Bulletin, Vol. 11 No. 2, March 1961.
12. HASL Report 88.

Dr. Friedlander is Associate Professor of Physics at Washington University in St. Louis.

BIOLOGICAL RISKS FROM PROJECT CHARIOT

by Barry Commoner

TO evaluate what harm could possibly result from the proposed Chariot explosion at Cape Thompson, Alaska, it is necessary to estimate how much of the resultant radioactivity may reach humans and important animals. Several kinds of information are needed. To begin with, we need to know how much radioactive fallout the blast is expected to produce; this problem is discussed in the article on page 5. But it is not enough simply to calculate how much fallout may reach the ground in the vicinity of the Chariot explosion. Fallout on the ground has almost no direct effect on humans and animals, for most of the radioactivity it gives off is of a type (beta activity) that does not penetrate very far into exposed objects.

The real problem arises in connection with the radioactive substances of fallout – especially strontium 90 – which enter the body along with food. Consequently, it is necessary to learn about the movement of Sr90 after it falls to the ground, and so determine how much of it is finally absorbed by the human body. The possible effects of fallout on people cannot be judged directly from the amount of Sr90 on the ground, since the proportion of the original Sr90 which eventually enters the human body will depend a great deal on the biological characteristics of the different animals and plants (especially their mineral nutrition) that serve as the links in the food chain carrying Sr90 from the ground into the human body.

Arctic Food Chain and Sr90

If the Chariot explosion were set off, let us say in Iowa, the problem of evaluating the possible effects of fallout would be relatively simple. A great deal of experimental work has been done to show how Sr90 moves through typical pasture soil, enters fodder, cattle, milk and other human foods, and is finally deposited in the human body. However, this food chain, typical of temperate regions, does not exist in the Arctic. The ground at Cape Thompson consists of permafrost – that is, the underlying zones are permanently frozen. The region has neither pastures nor domestic animals. A major human food is the caribou, which in turn eats lichens, a rather unusual plant which consists of an alga and a fungus living together. There is almost no basis for using experimental studies of Sr90 in pastures, cows and milk to predict what will happen in Alaska.

Ideally, what is needed are experiments on the Alaska situation, which would trace the passage of Sr90 through the unusual food chain of that area. Fortunately, some data are available on this point as a natural result of the world-wide distribution of fallout from past nuclear tests. In the last few years, the Sr90 contents of some animals and plants, and of a few human bones from Alaska, and from similar regions in Canada and Norway, have been measured. Also, several locations in Alaska have been included in the world-wide survey of Sr90 in soils carried out by the U. S. Department of Agriculture. From this information there emerges a rough picture of the biological path taken by Sr90 in the Alaska situation.

Sr90 Levels Low on the Ground

In 1959, the Sr90 on the ground in the northern part of Alaska, as a result of past nuclear testing, was rather low (about 10-22 mc/mi^2, i.e., millicuries per square mile) as compared with the levels found elsewhere in the U. S. (25-99 mc/mi^2; the average was about 50 mc/mi^2; Missouri ground Sr90 was about 86 mc/mi^2).[1] This is expected from the known behavior of stratospheric fallout, which is quite scanty near the poles. Thus, if the biological movement of Sr90 from soil into animals and man in northern Alaska were similar to the path taken in temperate zones, we would expect the Sr90 levels in Alaskans and in local animals to be considerably lower than those in people and animals elsewhere in the U. S.

TABLE I
Sr90 Content of Human Bones

	Alaska Samples*		Average for Western** Culture (U.S., Europe)
Age	Individual	Micromicrocuries Sr90 per gm. calcium	
4 months	Eskimo	2.42	2.5
7 years	Eskimo	3.35	1.2
25 years	Indian	0.18	0.3
26 years	Eskimo	1.94	0.3
53 years	Eskimo	0.47	0.3
61 years	Indian	0.59	0.3

* From "Radiological Health Data," Jan. 1961, page 41.
** From Kulp, Schulert and Hodges, *Science*, 132:448 (1960).

Why High Levels in Alaskans' Bones?

However, despite the relatively low level of fallout in northern Alaska, the few measurements that have been made on bones of Alaskans (Table I) show that their Sr90 contents are generally somewhat *higher* than those found in people of temperate zones. Some explanation of this discrepancy is essential before the possible effects of fallout from the proposed Chariot explosion can be considered. Measurements of the Sr90 contents of caribou give us an important clue. As shown in Table II, caribou, which provide a major part of the diet of Point Hope and Kivalina Eskimos, are unusually high in Sr90 content. Caribou bone (and antler) contains 100-200 strontium units (micromicrocuries Sr90 per gram of calcium), while bones of domestic animals raised elsewhere in the U. S. average about 25 strontium units.[2] The average Sr90 content of meat from U.S. domestic animals is about 1 micromicrocurie per kilogram,[3] while in caribou meat it is about 7 micromicrocuries.

Thus, the caribou appears to absorb unusually large amounts of Sr90 from fallout. That this is specifically related to the biology of the caribou is indicated by an interesting measurement reported from Norway[4] which shows that sheep and reindeer (which are very similar to caribou) raised in the same region have bone Sr90 levels of 17 and 100 strontium units respectively. Apparently caribou and reindeer have some way of selectively absorbing Sr90, or tend to eat food that is relatively rich in it.

How this comes about is strongly suggested by the available Sr90 data. Table II shows that the stomach contents of an Alaskan caribou contained a very high Sr90 level – 1,264 strontium units. By contrast, the stomach contents of cattle raised on the Nevada nuclear testing ground (which has ground Sr90 levels of 100-150 mc/mi^2 – about 5 or 6 times higher than northern Alaska's) have an average of only about 200 strontium units.[5] This suggests that caribou eat plants which for some reason are very high in Sr90 despite the fact that they grow on ground which is unusually *low* in Sr90.

Major Food of Caribou: Lichens

A key to this puzzle is provided by the particular food habits of the caribou (and reindeer), and by the unique biology of their major food – lichens. Lichens are not true plants in the usual sense; they do not form roots, and they lack the water- and food-conducting tubules present in ordinary plants. Conventional plants, which absorb most of their minerals via the roots, are to some degree protected from Sr90 because the fallout material is diluted by the natural minerals already present in the soil, and because in the absorption through the root there is considerable discrimination against Sr90.

Lichens do not have these advantages. A basic work on their physiology published in 1920 makes this quite plain. It states, with reference to the types of lichen that serve as caribou and reindeer food, that "the main source of water supply is from the atmosphere and the salts required in the metabolism of the cell must be obtained there also – from atmospheric dust dissolved in rain, or from wind-bourne particles deposited on the surface of the thallus (the lichen body) which may be gradually dissolved and absorbed . . ."[6]

Thus, such lichens literally obtain mineral nutrition from a kind of normal "fallout" – the dust carried down to the ground by rain and snow. This basic fact about lichen biology means that these organisms will take up some of their Sr90 directly from the fallout itself, in contrast to ordinary plants which absorb much Sr90 from the soil, where it has had a chance to be diluted.

TAELE II
Sr90 Content of North Alaska Food Sample

Food	Location	Collection Date	Strontium 90 Content: Micromicrocuries per kg. of sample	Strontium 90 Content: Micromicrocuries per gm. calcium (Strontium units)
Caribou meat	Anaktuvak Pass	Nov. '59	7	160
Caribou antlers	Anaktuvak River	Oct. '59	2948;4300	170;281
Caribou stomach contents	Anaktuvak River	Nov. '59	3,585	1,264
Whale meat	Point Hope	Oct. '59	less than .02	less than 2.4
Polar bear meat	Point Hope	Fall '59	less than .3	less than 2.8
Walrus meat	St. Lawrence	Spring '59	82	360
Needlefish	Hooper Bay	Oct. '59	275	7.6
Cod	Kotzebue	Oct. '59	165	7.9
White fish	Kobuk River	Spring '60	52-1087	3.6 - 62.4
Beluga meat	Kotzebue	Fall '59	.2-12	8.8 - 142.3
Plant roots	Shunguak	Oct. '59	48	16.7

"From Radiological Health Data," Jan. 1961, page 21.

Dust also a Factor

If this direct absorption of rain- and snow-precipitated fallout were the only route for Sr90 absorption by lichens, they would tend to show high levels of radioactivity only so long as fallout continued to descend to earth. If this were so, lichens would tend to avoid the prolonged absorption of the Sr90 already deposited on the earth, which, in the case of conventional soil-nourished plants, causes Sr90 content to remain relatively high even after fallout ceases. However, as indicated above, another important source of minerals for lichens is the dust that may be blown on them by the wind. Because of the strong winds in the Cape Thompson region, wind-blown displacement of soil is to be expected. Thus Foote reports from observations at Cape Hope that "During severe storms the blowing snow is usually mixed with sand."[7] This suggests that lichens may also absorb Sr90 which has already reached the soil, through dust deposited by the wind. This process would tend to prolong Sr90 absorption beyond the time when direct fallout stops. It would be important to know the relative contributions of direct fallout and dust-borne fallout to the Sr90 content of lichens. Unfortunately the only available Alaska data are for 1959, a period of high direct fallout. More recent measurements are needed if this question is to be answered.

Data Verifies High Sr90 Content of Lichens

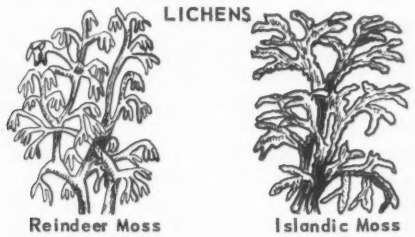
Available data bear out the expectation that lichens should contain especially high Sr90 levels. A direct comparison of Sr90 in various types of plants reported from studies in England shows that lichens take up several times more Sr90 from fallout than other plants in the same location.[8] Measurements of Sr90 in lichens have also been made as part of the Chariot studies, and although to our knowledge, no actual figures have been reported, the available reports do state that the Sr90 levels found in lichens, mosses and sedge (another caribou food) from the Ogotoruk Creek valley are higher than those in other local plants or animals.[9]

Thus one may conclude that because of the unique biological properties of lichens, and because of the fondness of caribou for lichens as food, these animals will tend to absorb Sr90 in unusually large amounts. This means that the caribou, and all animals that depend on lichens for food, must be expected to show unusually high Sr90 contents. That the few measurements of the bones of Alaska Eskimos, who use a great deal of caribou in their diet (Point Hope, with a population of 300 used about 140,000 pounds in one year), show relatively high Sr90 levels, is in keeping with this expectation.

Eskimo Diet Unusual

Although the Sr90 content of the Alaska Eskimo is undoubtedly due in part to the unusual food chain (i.e., lichens and caribou) on which he depends for much of his food, other factors may be important as well. The scanty data now available caution against the assumption that Sr90 absorption in Alaskans follows the same pattern as in men living in temperate zones. The Eskimo's diet is unusual – it contains virtually no starch and is especially rich in fat and meat. Presumably, the diet is very low in calcium, and very rich in vitamin D,

which is decisive in promoting calcium absorption. (Vitamin D is abundant in fish oils, e.g., codliver oil.) It is possible that the Eskimo's high vitamin D intake allows for unusually efficient calcium (and hence strontium) absorption. These considerations suggest that the relative efficiency of Sr90 absorption from the characteristic Eskimo diet may be very different from that of persons living on a diet typical of temperate zones. For these reasons, the fairly detailed knowledge that we have about the relation between Sr90 levels in diet and the amount that becomes deposited in the body – which is based almost exclusively on temperate zone diets – may not be directly applicable to Alaska. In the same way, much of what is known about the absorption of Sr90 by cattle, may not be applicable to Alaskan caribou.



Two Conclusions

To summarize what can be learned from the available information on Sr90 in the Alaska food chain, we can conclude that: a) certain unique biological relationships in Alaska (especially the lichen-caribou food chain) lead to an unusually efficient passage of Sr90 from fallout into animals, including humans; b) our actual knowledge of Sr90 absorption by Alaska Eskimos is very limited. For this reason, and because the probable physiological effects of the Eskimo's unique diet caution against direct transfer of conclusions based on Sr90 studies of inhabitants of temperate zones, predictions about Sr90 absorption by Eskimos cannot now be made.

In order to evaluate the possible effects of fallout from the proposed Chariot explosion we now need to correlate the foregoing conclusions with the available information about the amount and biological fate of fallout that may be expected from the test. The first part of this problem is discussed in the article on page 5, which concludes that the percent of total explosive yield which is spread as fallout cannot be accurately predicted at this time, and that values ranging from 5% (Livermore Laboratory's prediction) to 25% (Dr. Friedlander's) appear to be equally probable.

Fallout from Chariot will descend in an elongated zone. Radioactivity will be greatest at the point of the explosion, and will decline rapidly as one goes downwind. Using the above figures as limits for the expected vented yield, we find that at 28 miles from the explosion site, Sr90 on the ground might be anywhere from 370-3700 mc/mi^2; at 55 miles downwind, the level would be 37-370 mc/mi^2; at 82 miles, 3.7-37 mc/mi^2.

Amount of Fallout Reaching Food Chain

The amount of fallout which could get into the food chain depends on how much of it is absorbed by lichens; on the degree to which the fallout-contaminated lichens are eaten by caribou; and on how much Sr90 finds its way into the human diet from caribou and other sources.

It is probable that a considerable part of the Sr90 from Chariot fallout would eventually find its way into the lichens through the mechanisms described above. It has been suggested that if the explosion took place in early spring, the plants and soil would be protected by the snow which would catch the fallout and carry it out to sea in the spring thaw. However, Pruitt (see page 15) reports that because of the strong winds characteristic of the Ogotoruk Creek valley, nearly a third of the ground is blown free of snow. Also, if the snow-flushing mechanism were very important, it should have protected lichens from the heavy fallout resulting from the extensive nuclear testing in the latter half of 1958. There is no evidence of this in the 1959 data given in Table II. A few relatively simple isotope experiments might settle this question.

On the other hand it might be possible to limit caribou grazing in the fallout area to some extent by means of a fence around the most radioactive regions. Obviously this would be feasible in the immediate vicinity of the blast, where the fallout would be heaviest. We cannot predict how much fencing could be constructed and maintained in practice (consider for example the problem of snow drifts), but for the purpose of this discussion let us make the rather optimistic assumption that caribou can be excluded from a zone extending 28 miles downwind from the Chariot site.

If we now refer to the earlier article, we can see that the fallout area accessible to caribou under these assumed conditions (from the 28-mile line to points about 82 miles from the site), will have an average Sr90 level of 50-500 mc/mi^2. These values correspond to an increase over the *present* Sr90 levels in lichens (due to fallout from nuclear testing) of 2-20 times.

Fallout Effects on Sr90 Levels Difficult to Estimate

Such an increase in lichen Sr90 would not, however, lead to a corresponding increase in the Sr90 content of the caribou feeding on these lichens. The Alaska caribou herd wanders over a considerable range, and lichens consumed in the region affected by Chariot fallout will represent only some fraction of the herd's total diet. The studies carried out as part of the Chariot program's biological survey appear to be the first detailed observation on the movement of the Alaska caribou herd, and even these are far from complete.[10] Because of this uncertainty, and the difficulty of predicting the exact location of the fallout zone, it is hard to estimate, numerically, how much the Chariot fallout would affect the present Sr90 levels in caribou. However, even if the affected lichens represent only 10% of the herd's diet, the caribou Sr90 level – which as indicated above is already much higher than that of domestic animals elsewhere in the U. S. – might be doubled, if the upper estimate of released fallout (25%) proves to be true, and under the assumed success of efforts to prevent the animals from approaching closer than 28 miles to the explosion site. In the event that such extensive fencing proved impractical, the increase in caribou Sr90 might be several times greater.

Estimating the effect of Chariot fallout on the Sr90 content of people in the nearest villages is even more

uncertain. Since caribou meat is a major, but not the sole, source of Sr90 in their diet, these Eskimos might not experience the full effect of any increase in caribou Sr90. On the other hand, much of the caribou that they eat is killed in the general region of the Chariot site, which might tend to increase their Sr90 intake, depending on how long the caribou remain in the vicinity. Lack of knowledge regarding the Eskimo's strontium metabolism also adds to these uncertainties. Although it can be predicted that fallout from the Chariot blast would increase the level of Sr90 in the diet of the region's Eskimos, no accurate estimate of the size of the effect can be made without additional information not yet available.

The Possible Harm?

Finally we may ask if there is any possible harm associated with the Sr90 levels that may occur in the humans and animals that experience the effects of the Chariot explosion. The current biological approach to this problem as expressed, for example, in the most recent recommendations of the International Commission on Radiological Protection, is that *any* increase in in radiation exposure may carry with it some added risk of biological harm in the form of an increased rate in the incidence of genetic defects, or of radiation-induced disease such as cancer. The Federal Radiation Council, which has the responsibility for setting standards of radiation protection in the U. S., follows this approach, and suggests as a guide line for the general population, that a level of radioactivity of .17 rem (roentgen equivalent in man) for yearly whole-body exposure should not be exceeded.[11] This corresponds to about 17 strontium units in the bone (i.e., 17 micromicrocuries Sr90 per gram of calcium).

Ideally, what we need to know is the size of the gap between present Sr90 levels in Alaskans living near Cape Thompson, and the above Sr90 guide line. The problem relates specifically to children, since Sr90 deposition in bone is greatest during periods of growth. But as indicated in Table I, there are apparently only two Sr90 values on the bones of Eskimo children available at this time. Although one of the values (3.35 strontium units) is rather high for the age group, we do not know if it is representative. For a proper evaluation of this problem it would be important to have more information on the Sr90 in the bones of children in the villages of Point Hope and Kivalina.

Effects on Caribou Herd

It is also important to consider the possible effects of Chariot fallout on the health of the Alaska caribou herd, upon which the Eskimos now depend for food. The present levels of Sr90 in caribou bone – about 100-200 strontium units – are probably the highest found in any known food animals, and are, of course, well over the suggested limits for humans. These levels would certainly be increased by fallout from Chariot. But, since general knowledge of the effects of radiation on caribou health is essentially nil, it is difficult to assess the possible effects on the vitality of the caribou herd. Although there are no available data on the Sr90 content of grizzly bears in Alaska, these animals appear to feed on caribou considerably (see page 15), and may therefore be relatively high in Sr90. Since the grizzly bear is a source of income for operators of hunting camps, and since the animal is regarded by Alaska conservationists as being in danger of extinction, any increase in their present Sr90 levels may be significant.

Conclusion about Biological Hazard

From these considerations, we can reach the following conclusions about the biological hazard that would be imposed on life in the Cape Thompson region by the proposed nuclear explosions:

- Because of the unique mineral nutrition of the lichens, which avidly absorb fallout, the caribou – which feed on lichens – and the humans who eat the caribou, appear to be higher in Sr90 content than any other group in the world.
- The fallout from the proposed Chariot explosion will add to the present Sr90 levels by an amount that cannot now be estimated with any degree of precision.
- In the present state of knowledge about the effects of radiation, no firm prediction can be made regarding the ultimate harm that may result from either the present Sr90 levels, or from any increase that may be brought about by Chariot fallout. According to the current philosophy of radiation protection, however, it is assumed that every increase in radiation exposure carries with it an increased risk of disease.[12]

It should be noted that these conclusions are based almost exclusively on consideration of a single pathway of Sr90 into the human body, i. e., via lichens and caribou. Although a number of other Sr90-absorbing processes need to be considered as well, the necessary data are almost entirely lacking. Particularly important is the extent to which Sr90 might reach supplies of drinking water, stored foods (which are often preserved on outdoor platforms) and foods other than caribou. Data regarding other radioisotopes must also be obtained.

Among the required additional data, the following are probably of most importance:

a) Detailed measurements of Sr90 in soil, various plants and animals in North Alaska, over a period of time sufficient to establish trends.
b) A study of the mechanism of calcium and strontium absorption by lichens.
c) Establishment of the total dietary sources which serve the Alaska caribou herd, and their relations to Sr90.
d) Determination of the Sr90 content of all components in diet of Eskimos, especially at Point Hope and Kivalina.
e) A study of Sr90 absorption in Eskimo children, especially by means of Sr90 analyses of bones and teeth.
f) Basic studies of the physiology of calcium and strontium absorption in Eskimos.
g) Experiments to determine the degree to which snow-cover may protect underlying plants from fallout (for example by following the movements of an artificial isotope, such as Sr89 or Ca45, added to the snow).
h) Consideration of the degree to which radioactive isotopes other than Sr90 may add to the fallout hazard.
i) Experiments to determine how caribou can be excluded from particular grazing areas.

Until the results of these studies are available, the great uncertainty about its possible effect on life is perhaps the most serious problem which stands in the way of a decision on the wisdom of setting off the Chariot explosion. *(References on page 20)*

Dr. Commoner is Professor of Plant Physiology at Washington University in St. Louis.

CAPE THOMPSON

THE PEOPLE

by Don Charles Foote

THERE are several good reasons why man has been present in the Cape Thompson region for thousands of years.[1] Undoubtedly the most important is the availability of a variety of habitats for products of the land. Man is able to exist in the North on a permanent self-sufficient basis only by utilizing a seasonal succession of habitats. Only rarely can one habitat produce food and materials in variety and quantity sufficient to support a human population on a year-round occupancy. The Cape Thompson region is one of those few Arctic regions where a variety of habitats allows man to capitalize on moving ice for winter sealing, good caribou winter range for winter and spring hunting, bird-cliffs for summer egging and meat collection, large rivers and lagoons for fishing, a projecting piece of land (and moving ice) for spring whaling, mountains for winter and spring fur production, inland waters for late summer and autumn fishing. This is the real base of the human economy – the presence of a seasonal succession of habitats. It provides the basis of the life of the inhabitants of the two villages near Cape Thompson, Kivalina, and Point Hope.

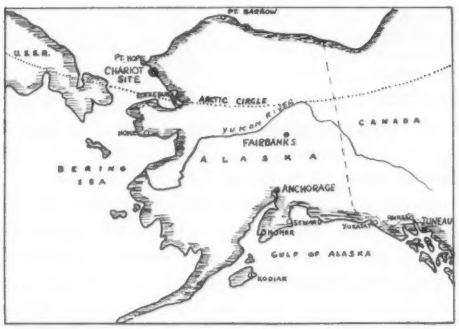
Kivalina

This village of 145 Eskimos is situated 40 miles southeast of Cape Thompson on a bar enclosing Corwin Lagoon. Into this lagoon empty the Wulik and Kivalina Rivers. The people of Kivalina are extremely dependent upon their natural resources for food as well as fuel. The availability of these resources varies with the seasons.[1] In the early fall the major emphasis is on fishing. The fish taken are equally divided between Dolly Varden Char and several species of Whitefish. Most of the fish are caught when they ascend the rivers. In 1959 the village took a total of 97,600 pounds of fish. They are prepared in a variety of ways – cooked or raw, frozen or dried or preserved in seal oil.

(Continued on page 14)

THE PLACE

THE OGOTORUK CREEK region, the site of Project Chariot (see map) situated where a mountain range meets the sea, is characterized by varied topography. Ogotoruk Valley is set in an upland varying from rolling to hilly to mountainous, while the valley floor itself is rolling.[1] The ridges are limestone and shale, and the valley floor is underlain by mudstone.



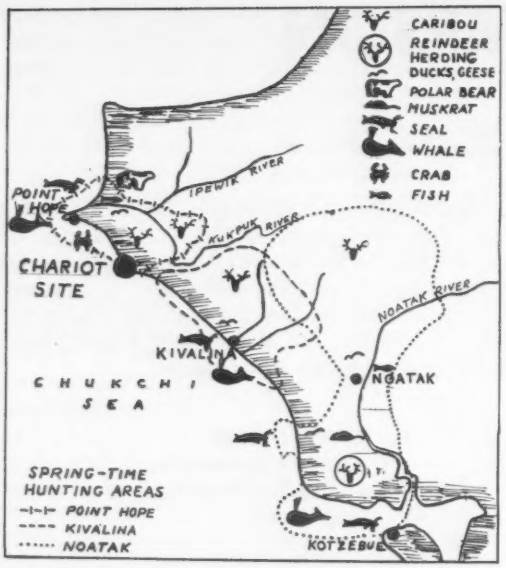
Map showing Chariot in relation to rest of Alaska.

The climate of the region is typically coastal Arctic, with short cool summers and long cold winters. Temperatures are rarely extremely low (below 35°F.), being modified by the nearness of the sea. The region is known for its strong, almost constant winds which result in very high windchill values.[2] These strong winds have remarkable effects on the winter snowfall. During the winter, some tributary valleys are almost completely filled with snow, but others are scoured clean by the wind. The uplands are frequently blown bare of snow, and much of the cotton-sedge tussock valley floor is also blown clear. Calculations in April 1960, at approximately the time of annual maximum snow accumulation, revealed that 29 percent of the Ogotoruk Valley was bare of snow.[2]

Because of currents and winds, the sea ice moves, forms, breaks up and reforms.[3] The winds sweeping down the Ogotoruk Valley frequently cause a large area of open water (measured in terms of square miles) to occur off the valley mouth.

Factors of special importance to Ogotoruk Valley plant and animal life are: a) The winds which clear away so much of the snow, which keep the adjacent sea relatively free of ice, and which result in very high windchill values; and b) the varied topography which results in a wide range of habitats for plants and animals.

(References on page 20)



Spring-time hunting patterns near Chariot site.

Caribou and other Hunting by Kivalina People

In the late fall the emphasis shifts to caribou hunting.[2] In 1959-1960 the greatest caribou hunting by Kivalina people took place in October and November in the Cape Seppings region, and in the winter in the region between the Wulik and Kivalina Rivers. In February 1960, the caribou hunting range began to move north into the Kukpuk drainage and in March it was in the region extending from the Kukpuk River to Cape Seppings and inland to the upper reaches of the Singoalik and Okpiksikruk Rivers.[3] From October 1959 through February 1960, a known total of 407 caribou were taken by Kivalina people. Caribou meat is eaten frozen, dried or preserved in seal oil, as well as cooked. It is hardly necessary to recount all the material things derived from caribou. Caribou skin clothing is a necessity for extended winter hunting activities. Caribou sinew is used for sewing. In Kivalina the manufacture of caribou hoof jewelry is a activity of growing economic importance.

At Kivalina, seal hunting begins in November. By December seal hunting on the sea ice is in full swing. During January and early February 1960, an open lead occurred at the edge of the land-fast ice some 4 or 5 miles from shore. In February the winds brought the ice pack back and closed the main lead, but the increasing hours of daylight caused an actual increase in the hunting. Seal hunting continued through April.

Bearded Seal hunting occurs in the spring, from April until the end of June or the first part of July. Bearded Seals are large animals, weighing up to 400 or 500 pounds. This type of hunting takes place on the sea ice between Kivalina and the Cape Seppings region.

Fur Trapping

Trapping for fur carries the Kivalina people far inland as well as up and down the coast. Wolf, wolverine, land otter and red fox are taken on trap lines extending 30 or 40 miles northeast of the village. Muskrat are trapped in the lowlands near the mouth of the Wulik River. White fox are taken on trap lines up the coast to Ogotoruk Creek and from some ten miles toward Cape Krusenstern.

The 1959 known take of marine mammals by Kivalina people is as follows: Ringed seal – 545, Bearded seal – 104, Beluga – 11. Data for 1960 are not yet available.

The 1959 and 1960 fur trapping data are not yet available. The take for 1958 is as follows: Colored fox – 5, White fox – 2, Muskrat – 12, Ground squirrel – 13, Wolf – 1, Wolverine – 10.

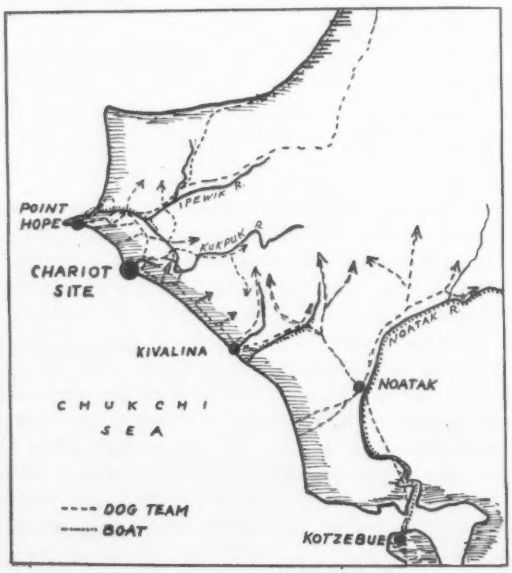
Point Hope

Point Hope, a village of about 300 inhabitants situated 30 miles northwest from Ogotoruk Creek, is one of the most successful Eskimo communities in the North American Arctic. It is successful because a talented and vigorous people have harmonized the cultural patterns of the modern European-American and traditional Eskimo. Wants and needs satisfied only by cash earnings are met through summer employment and the sale of native products, which in 1958-59 totaled about $100,000. The demands of the Eskimo way of life are fulfilled by the seasonal food gathering patterns. Simply said, in order to live at Point Hope, an independent and proud man must earn money and gather in his family's food from the rich flora and fauna of the environment.

To hunt at Point Hope requires a cash investment in weapons, boats, outboard motors, rifles, ammunition, tents, stoves and sundry other items. And to hunt at Point Hope means a constant effort to harvest food in its proper season and place. The hunter, like the farmer, must live in close harmony with his environment.

From September 1959 to September 1960, the people of Point Hope harvested approximately 400,000 pounds of meat from the ocean and the land. Point Hope hunters utilize apparently well over 1,000 seals (ringed and bearded) each year.[3, 4, 5]

(Continued on page 20)



Overland travel routes near Chariot site.

THE ANIMALS

by William O. Pruitt, Jr.

FIELD WORK on the mammals of the Cape Thompson region began in June 1959. In close cooperation with the botanical investigators we established a number of permanent one-acre sampling plots throughout the Ogotoruk valley. Several additional sampling plots have been added later. Our initial aims were, first, to find what kinds of mammals were present and in what numbers and, second, to block out their feeding relations.

Twenty Species of Land Mammals

Since the Ogotoruk Creek region lies at the western end of the Brooks Range, where these mountains break off into the Chukchi Sea, the topography there varies from rolling to hilly to mountainous. With such a great variation in topography the region possesses a wide range of terrestrial habitats for mammals – wet meadow, cotton-sedge tussocks, various types of frost-action polygons and terraces, talus slopes and dry ridge tops. Twenty species of land mammals are found there now: Tundra Shrew, Masked Shrew, Grizzly Bear, Polar Bear, Wolf, Red Fox, Arctic Fox, Wolverine, Ermine, Least Weasel, Arctic Ground Squirrel, Red-backed Vole, Muskrat, Brown Lemming, Collared Lemming, Porcupine, Caribou and Moose. Two species not found there today were present within the memory of men now living. These two species, Dall Sheep and Marmot, were extirpated locally probably by over-hunting because of the intensive Eskimo utilization of the region. [1, 2]

To a person familiar only with the temperate zone or the tropics, twenty species of land mammals does not appear impressive. But for an Arctic region this is a rich mammalian fauna. For example, southern Baffin Island in the Arctic Islands Game Preserve of Canada has 13 species, southern District of Keewatin in the Northwest Territories has 20 species, Southampton Island has 13 species and the magnificent country of Alaska's newly-created Arctic Wildlife Range has 24 species. Even Mount McKinley National Park has only 33 species.

The "Food Web" of Ogotoruk Region

Our second aim, that of blocking out the feeding relationships of these land mammals, has been carried out primarily by analyses of stomach contents and droppings of mammals and regurgitated pellets of carnivorous birds. We have outlined the flow of food in enough detail to recognize that there are three main utilizers of vegetation in the region – the voles and lemmings, the Arctic ground squirrel and the caribou. We have concentrated our studies on these three primary producers since almost everything else is a consumer of these herbivores, either directly or indirectly. The complex flow of energy in such a system is known as the "food web." Figure 1 shows the food web of the Ogotoruk region as far as we have been able to determine it. It is clear that many creatures,

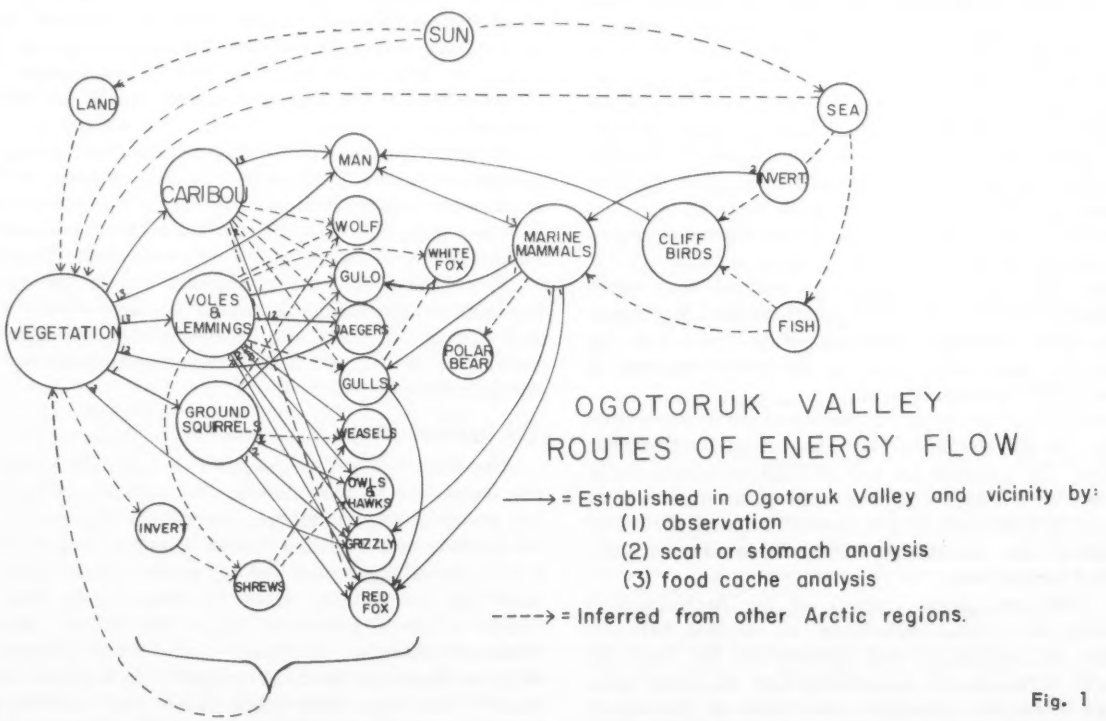


Fig. 1

from wolves to man, are dependent on the three major herbivores. Any change in any of these three would produce changes that would go reverberating through the food web to its most distant strands.

In the Ogotoruk region, as in all Northern regions, the populations of mammals undergo marked cyclic changes. When they are high, they are unbelievably high, and when they are low they practically disappear.

For example, 1959 was a high year in the Ogotoruk region for most kinds of small mammals and our sampling gave a biomass of Alaska Voles of about 3 pounds of mice per acre of habitat. This was undoubtedly the peak of their "high" because in 1960 the same sample plots produced only 3½ ounces of mice per acre of habitat.[2] One can see that the state of the cycle governs essentially everything else in the ecology of Northern regions. When the voles (or lemmings) are high, it seems as if everything – foxes, wolves, grizzlies, wolverines – subsist on them while numbers of carnivorous birds – owls, hawks, jaegers and ravens – congregate in the region.[3] Detailed study of changes in the food web throughout the progression of the cycle will be of great interest.

If the small mammal cycle in the Ogotoruk region has the same frequency as it does in other Arctic regions the voles will build up and be high again probably in 1963 or 1964. The small mammal population cycle of the Ogotoruk region is not in phase with the cycles in some other parts of the tundra regions of western and northern Alaska.

We do not know the basic causes of these population cycles. We do know something about their mechanisms, however. For example, in fall of 1959 we successfully predicted (by analysis of our field data on number of embryos and sex ratios) the general state of the cycle in 1960 in the case of the Arctic Shrew, Tundra Vole and Red-backed Vole.

In 1960 we began a study of the Arctic ground squirrel, using the techniques of marked animals, capture and recapture, and observation. We have restricted ourselves to a consideration of their basic biology while the botanists have taken up the aspect of ground squirrel-vegetation interrelationships. Our first year's work indicates the development of ideas of fundamental importance in such aspects of mammalogy as home range, territoriality and population dynamics.

Study of Caribou

Our study of caribou has been exceptionally rewarding. Knowledge of North American caribou, before the advent of the airplane, was based chiefly on folklore. Consequently, we have utilized light aircraft extensively, as well as conventional ground observations.

Barren-Ground caribou are commonly found in the Ogotoruk region, sometimes in great numbers.[4] Caribou perform extensive migrations and the individuals in the Ogotoruk region one month may be many miles away the following month, while they are replaced by other individuals streaming through.

The so-called "Arctic Herd" of Alaska caribou is estimated to number, conservatively, 200,000 animals. About 70,000 spend the winter in the region of our caribou studies – northwestern Alaska from Cape Lisburne south to the Kobuk River and from Point Hope eastward to about Howard Pass in the Brooks Range. These 70,000 are what we consider the "Ogotoruk caribou." All the villages in the area utilize these "Ogotoruk caribou." Great amounts of caribou meat are necessary to support not only the Eskimo villages of Point Hope and Kivalina, which have been studied intensively,[5] but also Noatak, Kotzebue, Noorvik, Kiana, Kobuk, Shungnak, Ambler, Point Lay, Wainwright, Barrow and others even farther removed from Ogotoruk itself.

In late October 1960, several thousand caribou utilized for the rut, the region northeast of Kivalina and just southeast of Ogotoruk.[6] Since adult bucks shed their antlers very soon after the rut, and since shed buck antlers have been commonly noted in the Ogotoruk valley, we conclude that in some years the caribou utilize the Ogotoruk valley itself for rutting grounds.

Project Chariot studies have shown that lichens and sedges in the Ogotoruk valley already contain far more radioactive contamination than any other plants (see article, page 9). On a yearly basis, the two most important caribou forage plants are lichens and sedges.

The Alaskan bush pilots long ago recognized the uniqueness of the Ogotoruk region because from the air they could see how this restricted region appeared brown or speckled in contrast to the white color of other Arctic regions.

The Ogotoruk Wind

The Ogotoruk valley, bounded on one side by Sahligvik Ridge and on the other by the Tahlaveerut Hills, is the mouth of a great topographic funnel which stretches for nearly a hundred miles inland. There is almost always a wind whistling through the tip of the funnel. Indeed, a point on the Kukpuk River 13 miles inland from the mouth of the Ogotoruk bears the Eskimo name of Ahneeyouyaktuvik, meaning "The place where the wind has hardened the snow so that a snow house can be built." Near this point sleds laden with caribou meat have been blown over by the wind. The naming of this spot is significant for it implies that not only is the

place here suitable for snow houses, but also that this is a restricted spot, measured in terms of acres, where there is *enough* snow for houses.

This famed Ogotoruk wind is actually the reason why the region is so important as a caribou winter range. The almost constant wind sweeps snow from the ridges, north-facing slopes and cotton-sedge tussocks. The creek valleys which lie across-wind are completely filled with snow that is as hard as concrete and the surface of which is carved and polished. The valleys that lie with the wind are scoured clean. Our study of the snow cover of the Ogotoruk region was done in April 1960, near the time of maximum snow accumulation. At this time I calculated that 29 percent of the Ogotoruk valley was bare of snow.

I have found that geographic variations in snow cover are of prime importance in governing the winter distribution of caribou. It comes as no surprise then to discover that a region such as the Ogotoruk, with little snow cover, is an important winter range for them.[7]

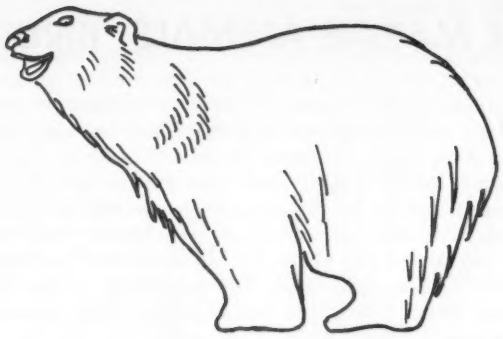
Arctic Carnivores

Since we now have some idea of the role of the herbivores in the Cape Thompson region, we plan to increase our work by giving more attention to the carnivores. Because Arctic carnivores, especially the larger ones, are wide-ranging and frequently are of rare species, we hope to obtain a goodly share of our data from carcasses taken for fur by the Eskimos of Point Hope and Kivalina who hunt and trap in our study region.

The "top carnivore" among land mammals of the Ogotoruk region is the Grizzly Bear. They have been extirpated over most of their original range and even in the country remaining to them they are usually rare. The Grizzly is considered by the National Wildlife Federation to be one of the kinds of North American mammals on the "danger list" threatened with extinction. In the Ogotoruk region Grizzlies are encountered with surprising frequency. In the Ogotoruk valley proper during June, July and August 1959, there were seven recorded observations of Grizzlies and during the comparable period in 1960 there were also seven observations. Once at 80 miles northeast from the mouth of Ogotoruk Creek I observed six Grizzlies within a mile of each other.

Another carnivore that is important in the food web is the Wolverine. The Ogotoruk region is excellent Wolverine habitat. I recall one raw windy day when I spent an entire afternoon observing an adult wolverine and two nearly-grown kits on the banks of the Ogotoruk. The kits would dig energetically for ground squirrels while the adult kept watch over where I thought I was so well-concealed. The Wolverine is also on the National Wildlife Federation's "danger list" of North American mammals threatened with extinction.

The present studies of terrestrial mammals in the Ogotoruk Creek region have been sponsored during 1959 and 1960 by the U.S. Atomic Energy Commission. I have included in this resume of the mammals, information gathered during personal acquaintance with the general region dating back to 1953. These studies have been oriented toward gaining a knowledge of the adaptations of mammals to the Arctic environment – adaptations not so much morphological and physiological as in the direction of behavior and population dynamics. The current



investigations provide a basic ecological framework and have not been designed to furnish data directly on the radiation or mechanical effects of Project Chariot. Such specialized studies must await the initial delimitation of the natural history of species and ecosystems.

Some Conclusions from Present Knowledge

From our present knowledge we may draw certain conclusions, however, about the land mammal fauna and about some possible dangers to it presented by Project Chariot. In numbers of species and numbers of individuals the Ogotoruk Creek region is relatively rich. Two kinds of land mammals in danger of extinction are encountered relatively frequently in the Ogotoruk Creek region. Several kinds of mammals of the region have great economic value as food, fur-bearers and as "game" for sports hunters. The Ogotoruk region serves as a winter range for caribou. This particular winter range is doubly important; first to the caribou themselves and secondly, to the humans who depend on them since it is readily available to two villages.

REFERENCES

1. Pruitt, W. O. et al., "Ogotoruk Mammal Investigations," Phase 11, Interim Final Report, June 1960.
2. Pruitt, W. O. et al., "Terrestrial Mammal Investigations, Ogotoruk Creek – Cape Thompson and Vicinity," Phase 11 Progress Report, December 1960.
3. Pitelka, F. A. et al., 1955. "Ecological Relationships of Jaegers and Owls as Lemming predators near Barrow, Alaska," Eco. Monog. 25: 85-117.
4. Lent, P. "Caribou Investigations, Northwest Alaska," Interim Report, June 1960.
5. Foote, D. C. "The Eskimo Hunter at Point Hope, Alaska: September 1959 to May 1960," June 1960.
6. Lent, P. "Caribou Investigations, Northwest Alaska," Progress Report, December 1960.
7. Pruitt, W. O. "Snow as a Factor in the Winter Ecology of the Barren Ground Caribou (*Rangifer Arcticus*)," Arctic 12: 159-179.

ERRATA

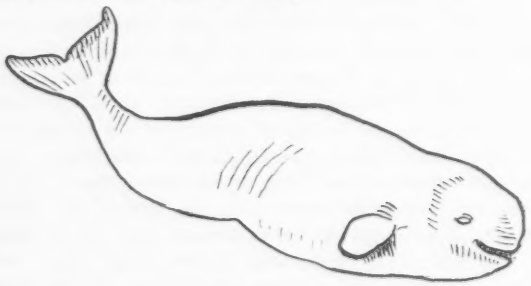
AN error was made in the June 1960 issue of *Nuclear Information.* In describing the fallout pattern of Project Chariot, the correct values are given for total gamma-ray dose at various distances from the explosion center. The diagram showing the fallout contours (see page 2 of that issue) explicitly labels the dose rates as total dose rates. The text, however (see page 3, paragraph 1), does not so identify them, and, by a parenthetical statement, the impression is given that they are daily dose rates.

Except for subsequent revisions in the entire project by the AEC, as described in the present *Nuclear Information,* the June issue is correct with the following changes (page 3, paragraph 1): 1) Substitute "lifetime gamma-ray dose" for the word "fallout" so that sentence reads: "Even this relatively low degree of radioactivity will mean that 10 roentgens of lifetime gamma-ray dose are expected 65 miles downwind from the site, and 0.1 roentgen as far as 300 miles downwind." 2) Delete the parenthetical statement that follows.

THE MARINE ANIMALS, BIRDS AND FISH

TEN species of marine mammals are known to occur regularly in the Ogotoruk region.[1] These are: Bowhead Whale, Gray Whale, Finback Whale, Killer Whale, Beluga, Porpoise, Ringed Seal, Harbor Seal, Ribbon Seal, Bearded Seal, and Walrus. In addition, other species such as the Alaska Fur Seal may occur as wanderers. The Polar Bear and Arctic Fox might also be considered as marine mammals for our purposes. The magnitude of the commerical Polar Bear guide business has been discussed elsewhere. Both the Polar Bear and the Arctic Fox are members of circumpolar wandering populations.

Our knowledge of the biology of the marine mammals is scant. Only sketchy numerical data on populations are available. For example, during 22 days of whaling at Point Hope in April and May 1960, a total of 124 "whales" were sighted. On February 6, 1960, 185 "seals" were counted on thin new ice off Crowbill Point, adjacent to the Ogotoruk Valley.[2]



The marine mammals are characterized by their extensive migrations and migration routes, one of which passes the mouth of Ogotoruk Creek and Point Hope. The Grey Whales overwinter off southern California while Walrus overwinter in the Bering Sea. In the spring, many of the large whales travel on to the east of Point Barrow and spend the summer in the Canadian Arctic. The distribution of many of the marine mammals is correlated with ice conditions – whether presence of ice, lack of ice, or ice covering a certain percentage of the sea. The Ringed Seal and Bearded Seal seem to be tied to the ice; Porpoises and Harbor Seals seem to avoid the ice, while the large whales, Beluga and Walrus are associated with particular amounts of ice cover. Thus for each species there is an annual cycle of presence or absence.

Sea-Cliff Birds

Sahligvik Ridge at Cape Thompson drops off into the sea in a sheer cliff. Here and for six miles northwestward, the coastline is formed by huge cliffs, interspersed with small creek valleys. Each year the crevices and ledges on the cliffs are utilized for nesting by several species of birds highly specialized for such an environment.[3] These are common Murres, Thick-billed Murres, Black Guillemots, Pigeon Guillemots, Horned Puffins, Tufted Puffins, Glaucous Gulls and Kittiwakes. Most of these species fly many miles out to sea to feed primarily on tiny fish. The sea-cliffs form an important part of the "food web." Some bird, such as Ravens, Peregrines and Gyrfalcons as well as Glaucous Gulls and Kittiwakes are "users," and depend on the fishing birds as "producers."

Censusing of the cliff colonies on the Cape Thompson vicinity has revealed that somewhat over 200,000 individual birds of several species are present.[3]

A very interesting aspect of the sea-cliff ecosystem is the presence of two species of Murres.[4] Several biological problems of importance are involved here. In the Cape Thompson region the two species occupy different types of ledges – Common Murres on long continuous ledges, usually on massive resistant dolomitic limestone, Thick-Billed Murres on lime-stone where the bedding is thinner, easily fractured and forming narrow discontinuous ledges. These highly specialized cliff-nesting birds thus possess strong behavoral restrictions in choice of nesting sites. In addition, social factors may govern their choice of nesting sites. There are several cliffs in northwestern Alaska which seem to fulfill the requirements for cliff-nesting birds, yet birds are not present on them. Other colonies are surrounded by cliffs that appear suitable as nesting sites, yet the colonies do not expand into them. While Murre colonies occur on the Diomede Islands and the Chamisso Islands, the vast majority of the Murre population in the entire Alaskan Arctic nests in the Cape Thompson-Cape Lisburne region.

Since the species of birds utilizing the sea-cliffs of northwestern Alaska include several that are highly specialized for such a markedly limited habitat, what will be the effects of the Chariot seismic and shock waves upon these habitats? It has been observed that Murres have not colonized the exposed face of the "new" cliff at Eezhrinyik (Cape Lewis), which was quite possibly formed at the time of the earthquake, the story of which was related by Rainey.[5]

What will be the fate of the side-ranging and biologically important birds at Cape Thompson, if their special nesting sites on the cliffs are destroyed by the Chariot blast?

Land Birds

Seventy-nine species of the terrestrial birds have been recorded from the Ogotoruk region.[6] The groups commonly known as "shorebirds" which usually are present in great numbers in coastal Arctic localities are mostly lacking in the Cape Thompson region. In contrast, more species of passerine or "perching" birds are present. Some of these passerine species are present in very substantial numbers. Very little is known about the biology of these species in the region, especially such aspects as population densities, fluctuations and productivity. Because of the geographic location of the Ogotoruk region such Siberian species as the Red-spotted Bluethroat and the Yellow Wagtail are found there. There is a great seasonal change in the avi-fauna of the Ogotoruk region. Eiders, murres, guillemots and Old-Squaw Ducks occur throughout the winter because of the open water present while Ravens, Rock Ptarmigan, Willow Ptarmigan and Gyrfalcons are also present.

(Continued on page 20)

THE PLANTS

by Leslie A. Viereck

THE GENERAL location of the Cape Thompson region is of great botanical significance. Being on the coast it possesses many shore plants that do not extend more than a few miles inland from the beach. Being the westward limit of the Brooks Range, it is the logical avenue for plant migrations from Asia to North America. Probably as recently as 11,000 years ago when the sea level was much lower, a lowland extended westward from the Cape Thompson region and connected it with the Asian mainland.[1] In the Cape Thompson region there is, then, a chance for a mixing of the Brooks Range plants, the coastal plants, the Arctic lowlands plants, and the Asian plants.

Asian Plants Present

The botanical investigations at Ogotoruk Creek bear this out.[2] On Sahilgvik Ridge (which forms the northwestern side of the Ogotoruk valley) grows a small lichen (*Evernia esorediosa*) which is an Asian plant known in North America only from this location. An Asian grass *(Koeleria asiatica)* grows quite commonly on the gravel bars of the streams in this area and is known outside of Asia only from the Cape Thompson region and a few locations in the Brooks Range. Another lichen *(Mastodia tesselata)*, found commonly on the bird cliffs of Cape Thompson and northward toward Cape Lisburne, is an eastern Asian species otherwise collected in North America only from the Queen Charlotte Islands.

Of further significance to the richness of the flora of the region is the presence of large areas of calcareous (limestone) rocks. Limestone rocks have often been noted by botanists to possess a distinctly different group of plants than those found on surrounding rocks.[2] Many plants often reach the limit of their geographic range in limestone. This is undoubtedly the reason that the Cape Thompson region forms the northern limit of several plants and extensions of range of several other species.[3] The common fireweed *(Epilosium angustifolium)*, for example, was found growing in this area, an extension of range from Kotzebue, a distance of 100 miles. In the summer of 1960 the Twinflower *(Linnaea borealis)* was found growing in a protected area many miles north of Cape Thompson, an extension of range of this small plant of nearly 150 miles.

Three Plant Communities Dominate

Part of the basic study of the Ogotoruk Valley has been to map the plant communities or vegetation units for the Ogotoruk Creek drainage, an area approximately 50 square miles.[3] Three plant communities dominate the landscape and account for 75 percent of the plant cover.

On the windswept ridges, of which there are many in the valley, a sparse low mat of Mountain Avens *(Dryas octopetala)* covers extensive areas. These ridges are swept by strong winds during the summer and blown free of snow in the winter. Very little soil develops on ridges and plants cover less than 50 percent of the group.

In the wetter, more protected slopes of the valley the tussock tundra covers large areas, being the most extensive vegetation type in the valley. It consists of the well-known cotton-grass tussocks (*Eriophorum vaginatum*), along with lichens, low ericaceous shrubs, and dwarf willows and birch. These tussocks furnish excellent protection and nesting sites for small mammals.

Arctic Sedge and Cotton Grass

In the wettest places, and usually where standing water is present throughout the summer, one finds a type of vegetation that has been called the "wet meadow." Sedges make up nearly a continuous and smooth mat over these extensive wet areas.

Many other plant communities are found in the Ogotoruk Valley and have been described in detail by the botanists. Many are associated with depressions that fill with snow in the winter, with solifluction processes, or with the gravel bars of the creek itself. All must be considered in a basic botanical survey of a region.

Importance of the Botanical Studies

The study of the vegetation of an area is important in itself and because the plants provide food and cover for the animals. The detailed study of the various plant communities is necessary as a basis for understanding all of the food energy relationships between the organisms of the tundra.

Important points brought out by the Botanical Studies are: a) The Cape Thompson region possesses a uniquely rich flora for an Arctic region. So far, 293 different species of flowering plants, 50 known species of mosses, and 67 known species of lichens have been recorded. This rich flora is undoubtedly due to the position of the Cape Thompson region at the Western end of the Brooks Range, its variety of bedrock (including limestone), and varied topography. b) Detailed analysis of the vegetation of Ogotoruk Creek has shown that lichens and sedges make up a large percentage of some of the main vegetation types listed above. On the exposed ridges with *Dryas*, lichens make up 51 percent of the cover; in the tussock type, sedges make up 40% and lichens 6%, while in the wet meadow types, sedges make up 50% of the plants. This finding is of particular importance because of the special tendencies of lichens to accumulate fallout radioactivity, and the dependence of caribou on lichens for food (see article, page 9).

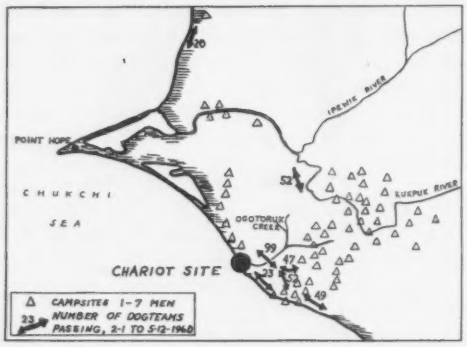
REFERENCES

1. Hulten, E., 1937, "Outline of the History of the Artic and Boreal Biota During the Quaternary Period," Stockholm, 168 pp.
2. Johnson, A. W. et al., "Ogotoruk Valley Botanical Project," Progress Report, Project Chariot, December, 1959.
3. Viereck, L. A. et al., "Ogotoruk Creek Botanical Investigations, Cape Thompson, Alaska," Phase III, Progress Report, December, 1960.

The People *(Continued from page 14)*

Inland Hunting Essential to Point Hope

Inland hunting by Point Hope men is essential for continued well-being in the village. Although a hunter may choose to hunt where and when he will, the usual seasons of land hunting are from mid-January to early December. Seasonal highs for inland hunting occur from September to December and mid-January to May.



Camp sites and overland travel near Chariot site.

Because an Eskimo hunter travels either by dog team or boat, he prefers to follow water courses as access highways which are frozen in winter, open in summer. Travel is absolutely necessary for a hunter because he must seek out his game. In autumn 1959, Point Hope people traveled by dog team more than 10,000 miles in five weeks. From Point Hope the traditional travel routes traverse the Kukpuk River or ocean shore and, in both cases, lead the hunters to Cape Thompson and the Ogotoruk Creek Valley. From October 1959 to May 1960, for example, 140 dog teams passed through Ogotoruk Creek. This figure represents the vast majority of Point Hope's men in addition to teams from Eskimo villages of Noatak and Kivalina. The Ogotoruk valley and its hinterland are, therefore, one of the major and important food gathering areas of the Point Hope people. During the fall of 1959 and spring of 1960, over 95 percent (more than 67,000 pounds) of all the caribou meat eaten in Point Hope was obtained within 25 miles directly inland from Project Chariot. Nearly 100 percent (15,000) of the village's fresh water fish came from a similar area during the fall of 1959.

REFERENCES

1. Rainey, F. 1947. "The Whale Hunters of Tigara," American Museum of Natural History, Anthropological Papers, Vol. 41: 229-283.
2. Saario, D. J. "Human Ecology Investigations, Kivalina, Alaska," December 1959.
3. Foote, D. C. "The Eskimo Hunter at Point Hope, Alaska, Part II, May to September, 1960," December 1960.
4. Foote, D. C. "The Eskimo Hunter at Point Hope, Alaska: September 1959 to May 1960," June 1960.
5. Foote, D. C. "The Economic Base and Seasonal Activities of Some Northwest Alaskan Villages," A preliminary Study, November 1959.

REFERENCES- The Place (see page 13)

1. Kachaddorian, R. et al., "Geologic Investigations in Support of Project Chariot in the Vicinity of Cape Thompson, Northwestern Alaska - - Preliminary Report," Trace Elements Investigations Report 753, U.S.G.S., January 1960.
2. Pruitt, W. O. et al., "Ogotoruk Mammal Investigations," Phase II, Interim final report, June 1960.
3. Bailey, A. M. and Hendee, A. R., 1926, "Notes on the Mammals of Northwestern Alaska," *J. Mamm.* 7 (1): 9-28.

The Marine Animals *(Continued from page 18)*

Fish

Because of the great seasonal variations in water level, because of the depth of winter freezing, and because the mouths of Ogotoruk Creek and other streams reaching the beach are frequently plugged by storm-raised gravel, very few species or individuals of fresh water fish are found in the Ogotoruk Region.[7] Several spots on the Kukpuk River sustain good populations of grayling, trout and various species of salmon.

Marine fishes fall into two groups – strictly marine forms, and those kinds that enter fresh water for breeding. Strictly marine fishes of commercial size and quantity are very few in the Ogotoruk region. A total of 43 species of marine fishes have been identified from the Chariot studies in the adjacent Chukchi Sea.[8] The data on species and number of individuals of small non-commercial marine fishes are indirect, resulting mainly from study of the pelagic-feeding cliff birds. Calculations of the magnitude of the sea-cliffs ecosystem reveal that the cliff-nesting birds of the Cape Thompson region consume some 50,000 pounds of marine life *per day*. Most of this is fish. Therefore there must exist tremendous populations of small marine fishes in order to furnish this much daily surplus on a sustained yield basis.

REFERENCES

1. Johnson, M. L. "Marine Mammal Investigations in the Cape Thompson Region," Interim Final Report, June 1960.
2. Foote, D. C. "The Eskimo Hunter at Point Hope, Alaska," September 1959 to May 1960," June 1960.
3. Swartz, L. G. "Sea Cliff Birds, Cape Thompson and Vicinity," Progress Report, December 1959.
4. Swartz, L. G. and Cox, G. W. "Investigations of Sea Cliff Birds, Cape Thompson, Alaska," Progress Report, December 1960.
5. Rainey, F. 1947. "The Whale Hunters of Tigara," American Museum of Natural History, Anthropological Papers, Vol. 41: 229-283.
6. Williamson, F. S. L. et al., "Avian Investigations in the Cape Thompson Region," Preliminary Report, November 1959.
7. Davis, J. J. et al., "Hanford Preliminary Evaluation Report of Project Chariot," Hanford Lab., Richland, Washington, December 1959.
8. Wilimovsky, N. In Preliminary Evaluation Report, Chariot Project, Phase II, Lab. of Radiation Biology, University of Washington, December 1959.

REFERENCES – Biological Risks (see page 9)

1. L. T. Alexander, "Strontium-90 on the Earth's Surface" in HASL 88 AEC, July 1, 1960.
2. AEC HASL 90.
3. Summary of data on Sr90 content of food and total diets in the U.S. NASL 90, AEC. Aug. 18, 1960.
4. Hvinden, T., "Radioaktivt ned fall, Norge" Tek. Ukeblad 38-39, 1958.
5. "Off-site Animal Investigation Project" AEC. in Radiological Health Data, Feb. 1961.
6. A. L. Smith, "Lichen." Cambridge U. Press, 1920.
7. D. C. Foote, "The Eskimo Hunter at Point Hope Alaska: Sept. 1959 to May 1960." June 1960.
8. E. Gorham, "A comparison of lower and higher plants as accumulations of radioactive fallout." Can. Jou. Bot. 37:327, (1959).
9. Quarterly Progress Report, Hanford Laboratories, HW66306, Aug. 5, 1960.
10. P. C. Lent, "Caribou Investigations, Northwest Alaska." Dec. 1960.
11. Radiation Protection Standards, Staff reports, Federal Radiation Council, May 13, 1960.
12. Recommendations of the International Commission on Radiological Protection, Adopted Sept. 9, 1958, Pergaman Press, New York, 1959.

The Greater St. Louis Citizens' COMMITTEE FOR NUCLEAR INFORMATION, founded in 1958, is the pioneer citizens' group in the field of nuclear education. CNI's program, a joint effort of scientists and laymen, is dedicated to making the known facts about nuclear energy and its effects better and more widely known. To do this, it assembles and studies available information on various nuclear problems, and presents the facts to the public, to scientists, and to the press.

CNI does not stand for or against particular policies. It presents the known facts for people to use in deciding where *they* stand on the moral and political questions of the nuclear age.

CNI publishes *Nuclear Information,* with a national circulation and provides the St. Louis area with a speakers bureau and scientific seminars. It also sponsors the Baby Tooth Survey, a ten-year scientific program to collect baby teeth as a way of monitoring the amount strontium 90 from fallout absorbed by St. Louis children.

You may order additional copies of this issue, "Project Chariot," at these rates:

1 copy	$ .50
10 copies	4.50
25 copies	10.00

(rates for larger quantities on request)

FILL OUT ➧

AND MAIL ➧

THIS COUPON ➧

CNI
6504 Delmar Blvd.
St. Louis 30, Mo.

Name_____

Street _____

City_____ Zone _____

State_____

Enclosed $_____

(Make checks payable to Committee for Nuclear Information.)

☐ Please send me _____ extra copies of "Project Chariot."

☐ Enter my one year subscription to *Nuclear Information.* ($2)

☐ Please accept my contribution of $_____ to CNI. (Contributions are tax-deductible.)

Greater St. Louis Citizens'
COMMITTEE FOR NUCLEAR INFORMATION
6504 Delmar Boulevard
St. Louis 30, Missouri

NON-PROFIT ORG.
U.S. Postage
PAID
St. Louis, Mo.
Permit No. 841

Mr. and Mrs. Walter C. Morgan
16 Cedarbrook Lane
St. Louis 22, Mo.

Form 3547 Requested.